5 CONCLUSIONS AND LESSONS LEARNED

An important role of government is to assure that public goods and the public interest are protected. In the 1960s, policymakers determined that vehicle safety fell into this category and determined that government needed to play a stronger role in protecting vehicle occupants. One outcome of this process was the adoption of a passive restraint requirement (FMVSS 208). Adoption of the rule was contentious, created large uncertainty for industry, and suffered long implementation delays. In retrospect, the process could have been more efficient. While we have not made a definitive analysis of the cost-effectiveness of the process or outcome, we note that other approaches could have been pursued. These information and education campaigns such as was done with anti-smoking,[95] mandatory seatbelt laws such as those successfully adopted in Australia, New Zealand, Canada, Sweden, and Germany,[96] prescriptive "technological fix" standards for airbags such as was done with ignition interlock systems, and economic incentives built into insurance premiums or other existing tax mechanisms.

All these approaches have advantages and disadvantages. Some would be less expensive, take less time to implement and even perhaps improve safety faster and more effectively. And some could be pursued concurrently. Indeed various approaches were pursued at various times, including public education, ignition interlock requirements, and automatic seatbelts. But policy and rule adoption is not a straightforward process. Many interests are at stake, and consumer and industry concerns are varied. Consumers resent and generally oppose mandated behavioral requirements. They want invisible technology fixes, but of course question the price increases that go along with those fixes. Automotive companies fear losing a competitive edge to other companies, and resist rules that add cost and reduce overall vehicle sales.

In the end, after gaining the public's confidence, airbags were widely embraced – even though the cost was not trivial. Indeed, from 1972 to 1991 changes in safety regulations increased the cost of manufacturing a new automobile by $900, while emissions regulations accounted for a $1400 added cost.[97] The analysis conducted by Dunham concluded that changes in emissions control and safety regulations have had similar cost impacts, but that consumers value safety more. He cited evidence that the introduction of new safety devices depressed the price of used cars, implying the high value of safety equipment. . He found no such price-depressing effect for emissions control equipment. The eventual acceptance of airbags was due to the combination of perceived value, virtual invisibility of airbags to vehicle users, and a perception that the requirements did not unduly favor any particular set of companies (such as non-US companies).

While the adversarial relationship between automakers and policymakers slowed the regulatory process, the relationship became more conciliatory over time – in large part due to customer embrace of safety.

5.1.1 Lessons Learned

Government regulation of the automobile industry has been a contentious and extremely important policymaking arena for the last 35 years. The primary objective of these regulations has been to maximize social and environmental benefits and minimize the negative economic impact on the automakers. The regulations need to be equitable across all of the different automakers, so as not to provide a competitive advantage for one over another. These regulations have had an enormous positive impact, while being implemented in such a way to keep the auto industry profitable and economically viable.

Below we identify some key lessons learned from the airbag experience that might be relevant to forthcoming greenhouse gas emission policy.

1. Automakers need to pass the cost of regulations on to consumers, and have a number of strategies to do so in ways that preserve profitability and sales volume. The more flexibility in the regulations, the more options available to automakers. In the case of passive restraints, the regulation at first attempted to specify acceptable alternatives to the airbag, namely automatic seatbelts, but this most likely did more harm than good since airbags proved to be the superior option. In the case of GHG regulation, automakers have a vast array of technological options available to lower GHG emissions. The airbag experience suggests that the broadest performance-based rules, with some flexibility in the phase-in schedule, are most desirable.

2. The cost of complying with passive restraint regulations, while overall quite significant, was typically small compared with the year-to-year variability in vehicle prices. Appendix A highlights price and sales changes for a number of vehicle models from a number of different manufacturers. The figures in the Appendix show a great deal of fluctuation from model year to model year without clear links to compliance costs or non-regulated improvements to the vehicle.

3. Inconsistent policy and a willingness to compromise led to ineffectual rulemaking and long delays in the case of airbags. While rulemaking flexibility is desirable, consistency and clear direction leads to a more efficient process. Between 1970 and 1984 the discussion of a passive restraint standard was in full swing, but an actual regulation was never passed and the benefits of such a regulation were forfeited. Even between 1984 and 1991, the regulation was not as direct as could be, which resulted in a lower benefit-cost ratio than could have been achieved. With GHG regulation, the regulation should convey the purpose and necessity in the process from start to finish.

4. Despite the strong opposition toward airbags based on cost and other considerations from automakers, it can be argued that the airbag standard has had a positive effect on the auto industry. The addition of airbags corresponded with higher consumer valuations of safety in general, and has led to a new growth industry that consumers value, and that saves lives and prevent injuries: a win-win solution. There is evidence that consumers have consistently valued the environment to a greater extent over time. By matching the regulation to a growing concern of consumers, regulators and automakers can create a smoother transition for the new technology that benefits all parties involved. In other words, if the public stand firmly behind the regulation, the job of implementing a standard will be greatly facilitated.

5. Truly independent government and private research reports are vital to fully understanding the costs and benefits of a potential regulation, and the policy options available to attain policy objectives. In the case of airbags, there was a great deal of conflicting evidence with respect to cost of compliance, consumer sentiment, and safety benefits of airbag technology. Advocates on either side of the debate tended to overestimate or underestimate findings based on their particular advocacy stance. One example involves automakers grossly overestimating the cost of compliance, and concluding from the high costs that there would be disastrous macroeconomic impacts due to the regulation. Another example involves government and insurance industry officials estimating benefits of lives saved and injuries reduced too optimistically. An example of a helpful, impartial analysis involved respected economist William Nordhaus, who had in the past tended to favor less regulation. Nordhaus conducted an analysis and filed a report stating that the rescission of the passive restraint standard would have a negative economic impact. This report was respected on both sides and was difficult to repudiate. With GHG regulation, both sides (government and environmental groups on one side and automakers and pro-business interests) should strive toward following impartial, scientific findings over stubborn ideological stances.

6. Advertising and marketing efforts by automakers themselves as well as other groups such as auto insurers assisted greatly in the transition to an airbag-equipped vehicle fleet. Consumers are skeptical of new technologies they do not understand, and while recognizing a problem such as deaths and injuries from automobile accidents or global warming, may not link these problems to their behavior or to potential solutions. Automakers like Mercedes-Benz and Chrysler showed through their advertising how an airbag worked and how it could save your life. For automakers, it is a difficult position because they are implicitly acknowledging that their products can lead to death and injury, or in the case of GHG regulation, contribute to global climate change. Automakers can receive beneficial 'halo effects' from promoting safety or environmental stewardship, and such business benefits will only increase as awareness of environmental problems and their link to light-duty vehicle use is increased.

7. The added cost of regulation will typically lead to a higher average price per vehicle, but this itself may have little effect on vehicle sales. Compliance cost can be recouped through a number of different approaches as shown in the report. In the case of airbags, the least expensive, most price-sensitive cars tended to have disproportionately lower price increases. It was also discovered that price setting is a fluid and complex process, which reflects a number of corporate goals including, but certainly not limited to, cost recovery. For moderate cost increases (<5% of average vehicle cost) due to regulation, automakers have shown adeptness at meeting regulation and maintaining sales volume. There is no reason to believe a GHG emissions regulation would be any different.

8. The costs of new technologies added to meet a given regulation decline quickly as economies of scale and learning effects are achieved. In the case of airbags, the cost or airbags fell dramatically as large volume production began. Cost not only fell, but quality and performance of airbag systems grew rapidly through the 1990s, and continues to grow to this day. It is important to fully analyze the cost differences between lower production schedules and high volume. If a handful of technologies are employed across all vehicles to meet a future GHG regulation, the costs of the added equipment will fall quickly, which should allow sufficient profit margins to be maintained.

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ABBREVIATIONS

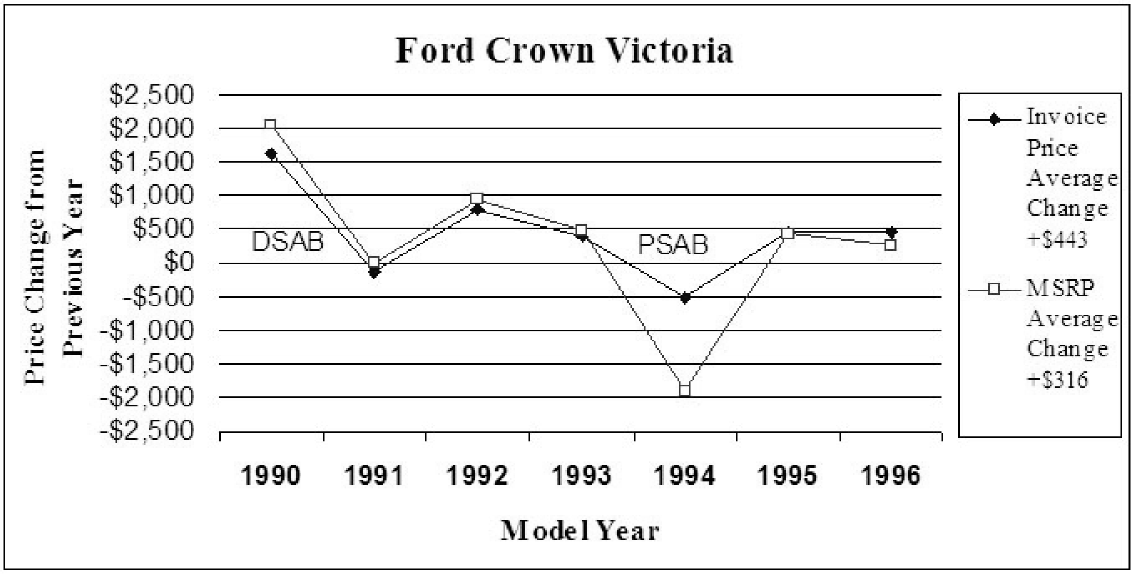
AAA – American Automobile Association
ABS – Anti-Lock Braking Systems
AOPA – Automobile Occupant Protection Association
CAS – Center for Auto Safety
DOT – Department of Transportation
EPA – Environmental Protection Agency
FHWA – Federal Highway Administration
FMVSS – Federal Motor Vehicle Safety Standards (e.g. FMVSS 208)
GAO – General Accounting Office
GHG – Greenhouse Gases
GM – General Motors
GSA – General Services Administration
IIHS – Insurance Institute for Highway Safety
ISTEA – Intermodal Surface Transportation Efficiency Act of 1991
NHSB – National Highway Safety Bureau
NHTSA – National Highway Traffic Safety Bureau
NMVSAC – National Motor Vehicle Safety Advisory Council
OEM – Original Equipment Manufacturer
RPE – Retail Price Equivalent
USAA – United Services Automobile Association

APPENDICES

APPENDIX A: CHANGES IN PRICE AND SALES VOLUME FOR 27 PASSENGER CARS

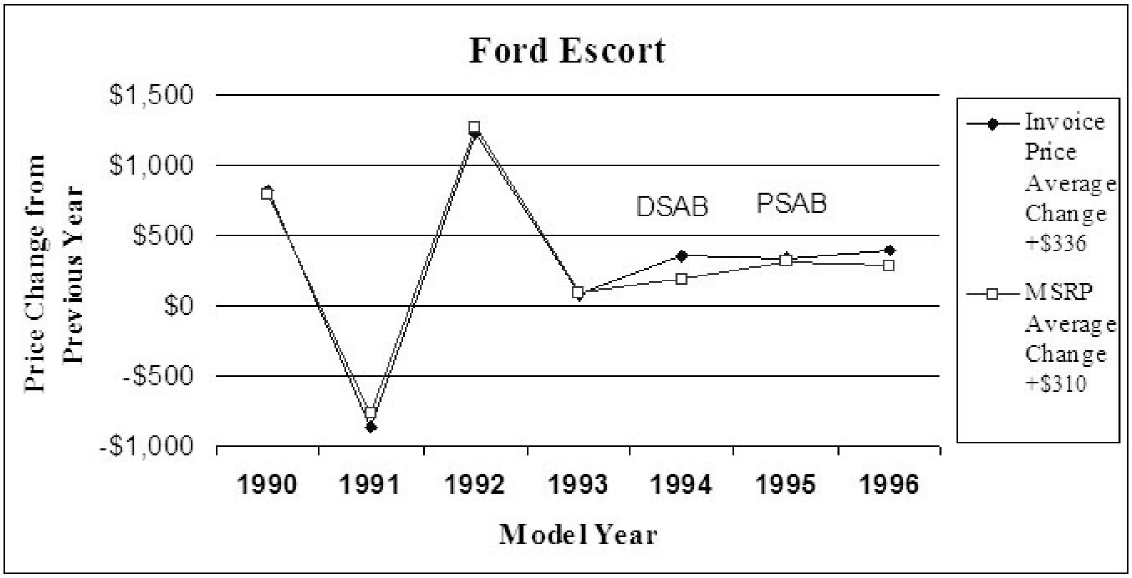
An important level of detail is lost when observing aggregate price changes. For example, the effect of when automakers lower prices on some cars while raising prices on others would merge into a mean thus nullifying the full effects. Incorporating a disaggregate approach into the analysis will help flesh out these important pricing subtleties. This Appendix contains a set of graphs that depict price change from the previous year of a number of representative car models over the1989 through 1996 model years when the integration of airbags into vehicles was at its highest rate. The prices are adjusted to constant 2002$ using the new vehicle consumer price index (CPI) furnished by the Bureau of Labor Statistics. The source used for the price and optional and standard equipment was the annual automotive issue of *Consumer's Digest*. The series in the particular model group was the base vehicle unless otherwise noted. The sales data for these models are also included, as well as the percentage of sales for a particular make attributable to that vehicle. The make is considered to be Chevrolet or Lincoln-Mercury, for example, and not General Motors or Ford Motor Co. *Ward's Automotive Yearbook* is the source for annual sales data.

Manufacturers often introduced airbags into vehicles with little styling change if any at all, which allows an analysis of this type to be fruitful. For example, when Chrysler introduced driver-side airbags into virtually the entire line of its domestically produced passenger cars for the 1990 model year, the cars underwent minimal styling modifications.[1] On the other hand, GM employed the opposite philosophy when it regularly introduced airbags jointly with styling changes. An analysis that looked at short-run profit maximization in the auto industry determined that domestic automakers raise prices significantly on models that undergo a major vehicle restyling, but no evidence indicated that Japanese manufacturers consistently exhibited this pricing behavior over the 1977-1992 period.[2]



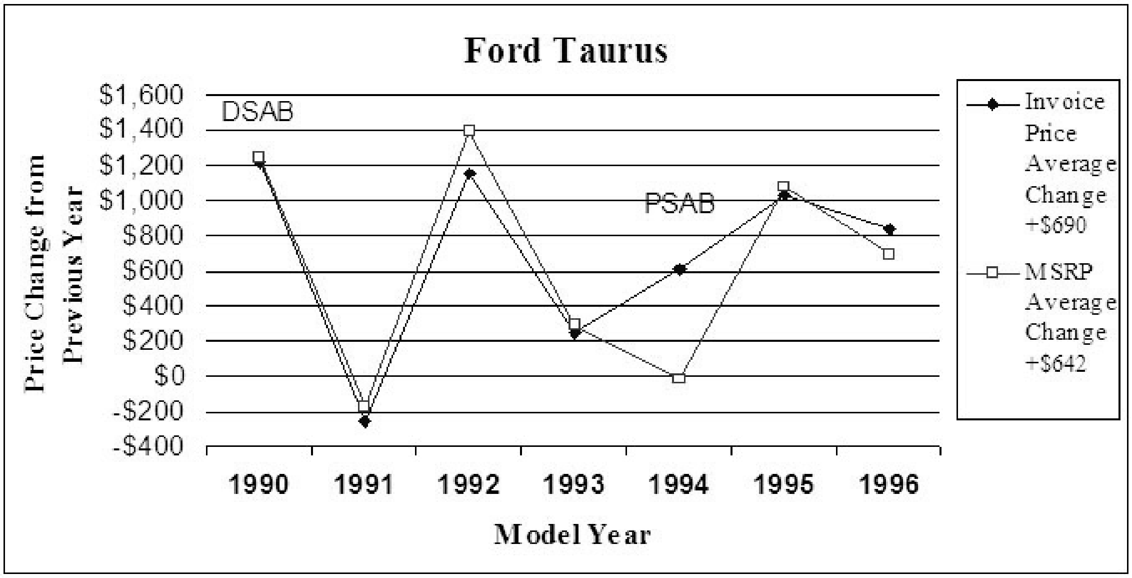
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		114,257	107,724	85,406	90,804	99,860	103,653	96,458	106,211
% of Make		7.2%	8.1%	7.7%	7.8%	7.7%	7.7%	7.2%	8.5%
Inv.	Current$	$13,663	$15,300	$15,724	$16,864	$17,654	$17,743	$18,601	$19,402
Inv.	2002$	$15,738	$17,361	$17,230	$18,033	$18,433	$17,913	$18,374	$18,839
MSRP	Current$	$15,581	$17,611	$18,227	$19,563	$20,493	$19,300	$20,160	$20,760
MSRP	2002$	$17,947	$19,983	$19,973	$20,919	$21,397	$19,484	$19,913	$20,158

For the 1990 model year Ford made standard a driver airbag, but raised the MSRP roughly $2000. The 1990 Crown Victoria also added power windows and mirrors, an auto parking braking release, and a tilt steering wheel as standard equipment, as well as a great many more optional equipment offerings including a number of preferred equipment packages. In 1991 no new standard equipment was offered, and in 1992 not much new was added, but the design was described as “all-new” and “modern.” For the 1994 model year a passenger airbag was made standard accompanied by a substantial price decrease. This was an unusual pricing practice because there was no observable decontenting, so clearly there was an ulterior driver at work besides passing on the added cost of the airbag to the consumer. The profit margin for the dealer shrunk considerably since the wholesale price fell only a quarter as much as the MSRP. During this timeframe, the sales volume as a percentage of Ford’s total sales remained consistent with the biggest jumps occurring with the addition of a driver airbag in 1990 and then again in 1996.



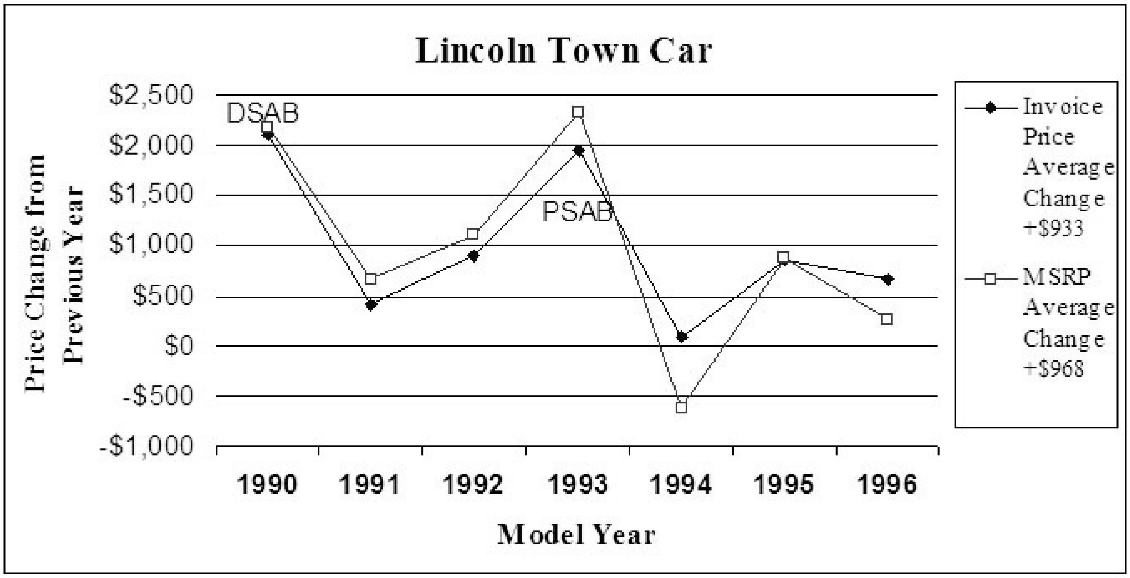
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		366,354	277,262	264,363	244,321	241,279	326,757	301,617	292,900
% of Make		23.1%	20.8%	23.7%	21.1%	18.6%	24.4%	22.6%	23.4%
Inv.	Current$	$6,915	$7,738	$7,230	$8,559	$8,839	$9,496	$10,042	$10,627
Inv.	2002$	$7,965	$8,780	$7,922	$9,152	$9,229	$9,587	$9,919	$10,319
MSRP	Current$	$7,679	$8,492	$8,095	$9,483	$9,797	$10,325	$10,870	$11,345
MSRP	2002$	$8,845	$9,636	$8,870	$10,140	$10,229	$10,424	$10,737	$11,016

The LX 4-door hatchback was used for the analysis, but a great deal of Δ price variance was observed among the different series of Escorts. There was little to no change in standard equipment on the subcompact car other than the inclusion of airbags during this timeframe. As a low-priced, economy car, Ford had very little room both in price and equipment with which to maneuver. Possibly due in part to the newly standard driver airbag, sales surged in 1994, although that year experienced an industry-wide peak in sales as well.



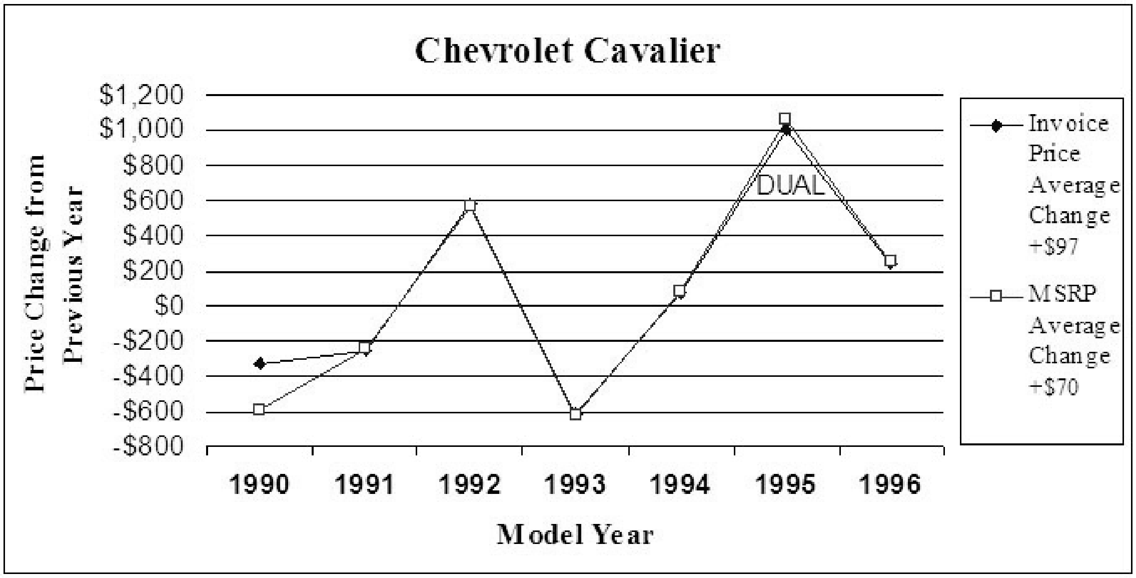
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		360,237	316,906	296,623	347,534	399,573	380,842	397,763	378,144
% of Make		22.8%	23.8%	26.6%	30.0%	30.8%	28.4%	29.8%	30.2%
Inv.	Current$	$10,152	$11,381	$11,548	$12,908	$13,455	$14,519	$15,887	$17,019
Inv.	2002$	$11,694	$12,914	$12,654	$13,803	$14,048	$14,658	$15,693	$16,526
MSRP	Current$	$11,778	$13,044	$13,352	$14,980	$15,623	$16,140	$17,585	$18,600
MSRP	2002$	$13,566	$14,801	$14,631	$16,018	$16,312	$16,294	$17,370	$18,061

The $1200 increase in price when the driver airbag was added for the 1990 model year is a clear example of the automaker passing on the cost of the airbag to the consumer. Power mirrors and tilt steering were also new equipment, but the much costlier airbag is most likely the source for much of the price spike. Ford made the power mirrors optional when the company introduced the 1994 Taurus with dual airbags and a virtually unchanged sticker price. Again the profit margin for the dealer was squeezed. The following year the price jumped about $1000 due at least in part to air conditioning, a rear defroster and power mirrors all being made standard. Air conditioning alone had been priced in the neighborhood of $700 as an option.



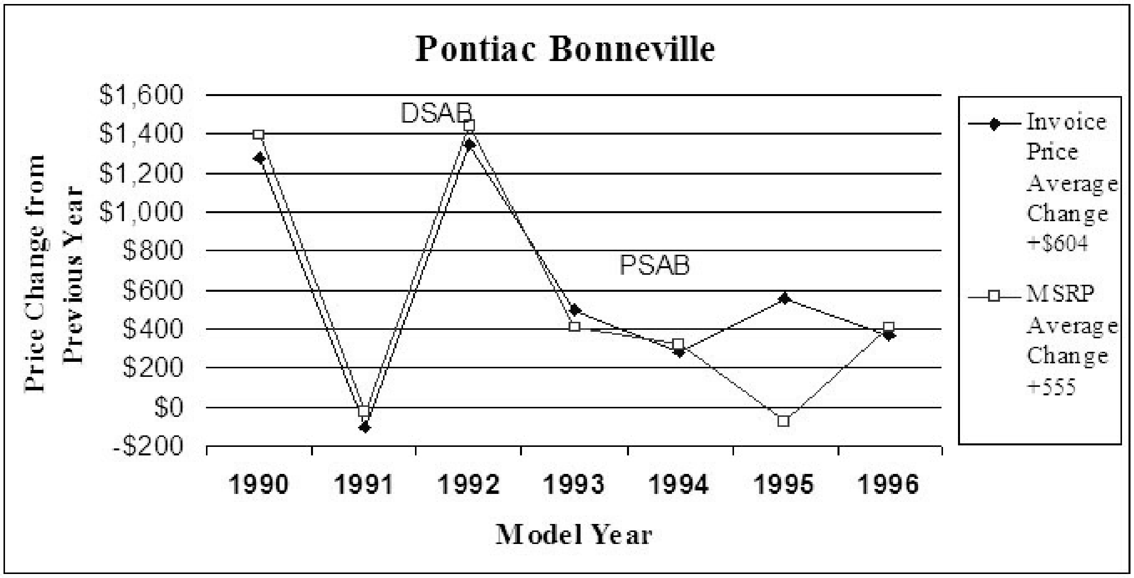
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		117,806	141,157	126,987	111,697	110,371	118,300	103,045	92,426
% of Make		16.9%	23.0%	22.4%	20.1%	18.9%	20.9%	19.2%	18.4%
Inv.	Current$	$21,721	$23,893	$25,128	$26,577	$29,080	$30,166	$31,699	$32,928
Inv.	2002$	$25,019	$27,112	$27,535	$28,419	$30,363	$30,454	$31,311	$31,973
MSRP	Current$	$25,562	$27,865	$29,458	$31,211	$34,190	$34,750	$36,400	$37,300
MSRP	2002$	$29,443	$31,619	$32,279	$33,374	$35,698	$35,082	$35,955	$36,218

The Lincoln Town Car is one of the highest-end production cars built by Ford Motor Co. Judging from the large price spikes of $2000 or more each when driver and then passenger airbags were introduced, the company could be recouping much of its airbag development and production costs through the greater profits generated from their luxury cars. ABS ($787 option) were also made standard along with the passenger airbag ($415 option) on 1993 models.



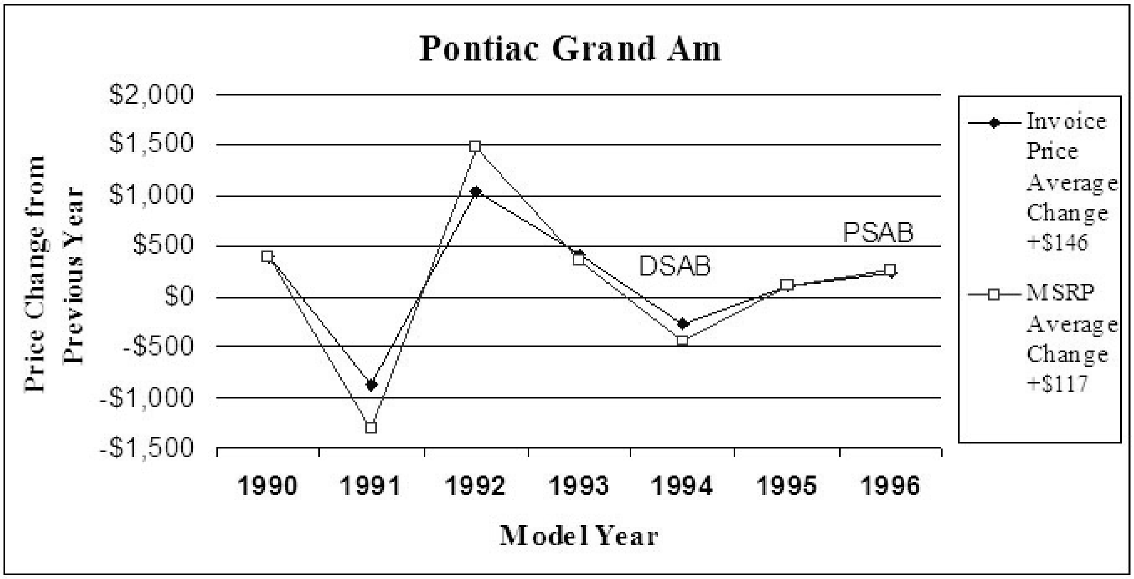
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		306,518	288,029	281,378	212,675	249,388	247,029	162,984	277,352
% of Make		21.8%	21.3%	23.7%	20.5%	24.8%	24.0%	16.0%	24.8%
Inv.	Current$	$7,934	$7,759	$7,799	$8,531	$8,146	$8,501	$9,701	$10,112
Inv.	2002$	$9,139	$8,804	$8,546	$9,122	$8,505	$8,582	$9,582	$9,819
MSRP	Current$	$8,595	$8,202	$8,270	$8,999	$8,620	$8,995	$10,265	$10,700
MSRP	2002$	$9,900	$9,307	$9,062	$9,623	$9,000	$9,081	$10,139	$10,390

The Cavalier is another example of the firm passing on the cost of airbags to consumers. A sensitive price elasticity can also be inferred qualitatively from the data. The 1992 model year saw an increase in price of $600 and a resultant drop in sales of nearly 70,000 cars. The following year GM reversed the price change and lowered the MSRP $600 and sales bounced back. When dual airbags were finally installed in 1995 and the cost looked to be passed on to the tune of $1000, the percentage of Chevrolet sales attributable to Cavalier fell from nearly a quarter to under a sixth. The extreme price sensitivity of the Cavalier is the reason the average annual price hike is under $100.



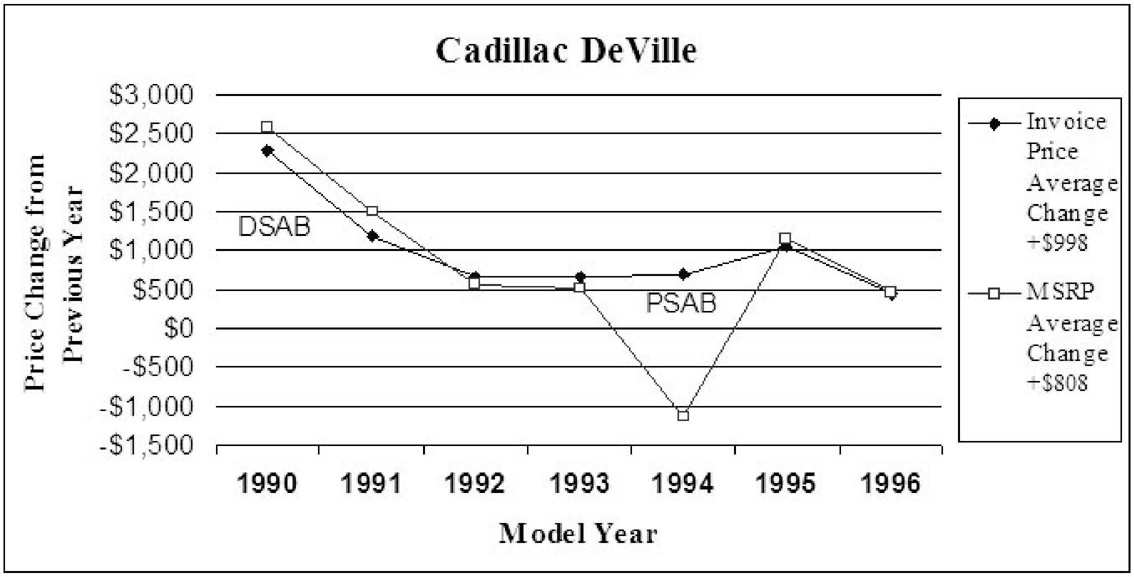
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		94,761	69,322	64,349	98,595	91,643	92,672	82,954	78,554
% of Make		12.9%	10.9%	12.5%	19.0%	17.6%	15.4%	15.0%	14.6%
Inv.	Current$	$12,798	$14,118	$14,527	$16,144	$17,014	$17,871	$18,828	$19,539
Inv.	2002$	$14,741	$16,020	$15,918	$17,263	$17,764	$18,042	$18,598	$18,972
MSRP	Current$	$14,829	$16,279	$16,834	$18,599	$19,444	$20,424	$20,804	$21,589
MSRP	2002$	$17,081	$18,472	$18,446	$19,888	$20,302	$20,619	$20,550	$20,963

Unlike the Cavalier, sales of the Bonneville do not exhibit price sensitivity. The best sales year in this timeframe was 1992 when a driver airbag was made standard, and the price of the optional ABS fell from$787 to $383. In the following two model years, GM made standard first ABS, and then passenger airbags with a below average increase in vehicle price.



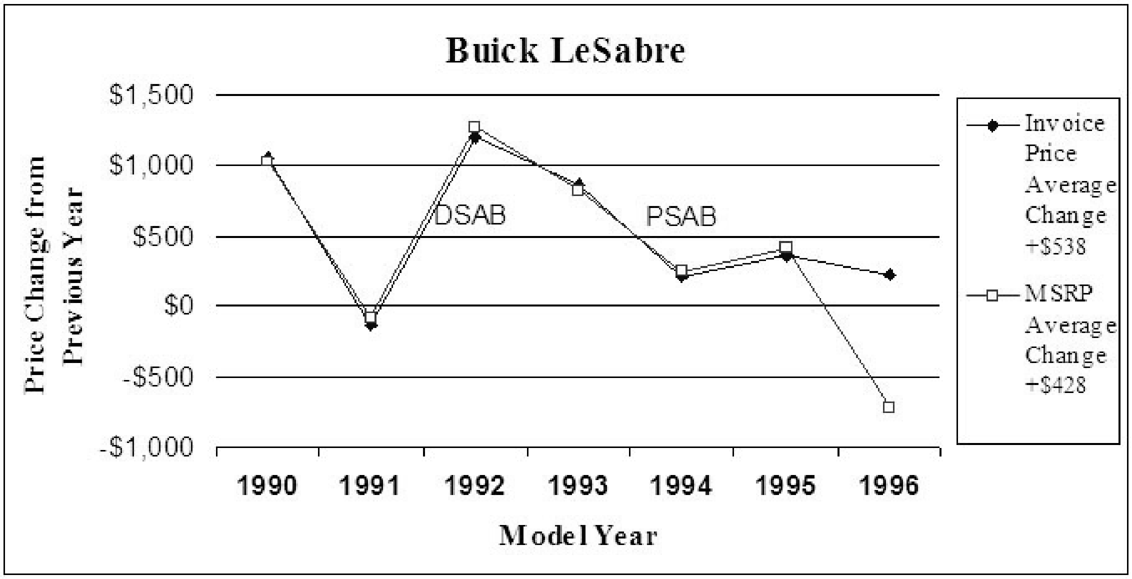
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		217,169	208,813	151,320	198,596	211,544	243,682	246,778	224,530
% of Make		29.6%	32.9%	29.4%	38.3%	40.6%	40.5%	44.7%	41.6%
Inv.	Current$	$9,528	$10,019	$9,576	$10,775	$11,425	$11,542	$11,899	$12,352
Inv.	2002$	$10,975	$11,369	$10,493	$11,522	$11,929	$11,652	$11,753	$11,994
MSRP	Current$	$10,669	$11,169	$10,374	$11,999	$12,624	$12,614	$13,004	$13,499
MSRP	2002$	$12,289	$12,674	$11,368	$12,831	$13,181	$12,735	$12,845	$13,108

The Grand Am is an affordable compact car like the Cavalier, but is somewhat sportier, and its sales and pricing behavior are markedly different. The Grand Am also received airbags relatively late, and with an average price hike of about $0 between the two model years when airbags were introduced, it is clear that GM wasn't passing the cost on directly, at least in the short run. When ABS and fog lights were made standard on 1992 models, the price increase was significant, but the sales did not suffer. Sales were at the highest in 1994 and 1995 when a car buyer could get standard ABS and an airbag in a sporty package for under $13,000.



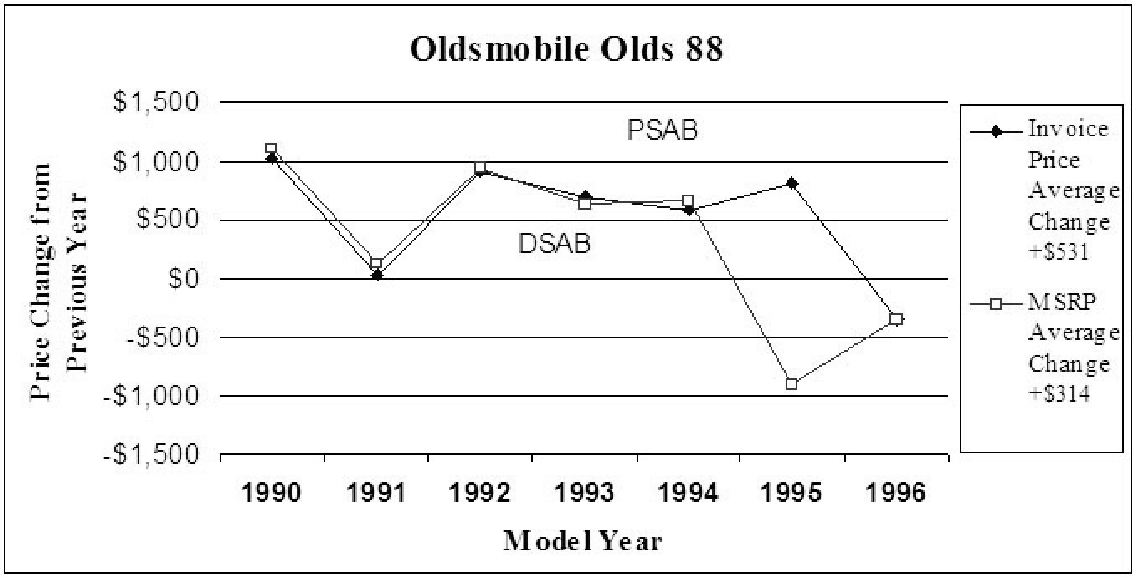
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		177,907	163,542	147,251	136,238	122,173	115,935	110,830	108,349
% of Make		64.6%	63.7%	67.4%	63.8%	57.8%	55.4%	60.5%	61.5%
Inv.	Current$	$21,697	$24,042	$25,979	$27,233	$28,537	$30,186	$31,934	$32,936
Inv.	2002$	$24,992	$27,281	$28,467	$29,121	$29,796	$30,475	$31,543	$31,981
MSRP	Current$	$25,435	$28,090	$30,455	$31,740	$32,990	$32,990	$34,900	$35,995
MSRP	2002$	$29,297	$31,874	$33,372	$33,940	$34,445	$33,305	$34,473	$34,951

Sales of the DeVille declined consistently during this timeframe, probably due more to cultural currents and consumer tastes, than anything quantifiable. For instance, many consumers who would have considered a DeVille were now in the market for an SUV. The 1990 model year was the first time GM offered standard airbag and ABS, and if the price increase of the DeVille is any indication, the company was trying to recoup its investment in a hurry. The price stabilized for the rest of the period perhaps in response to the slumping sales.



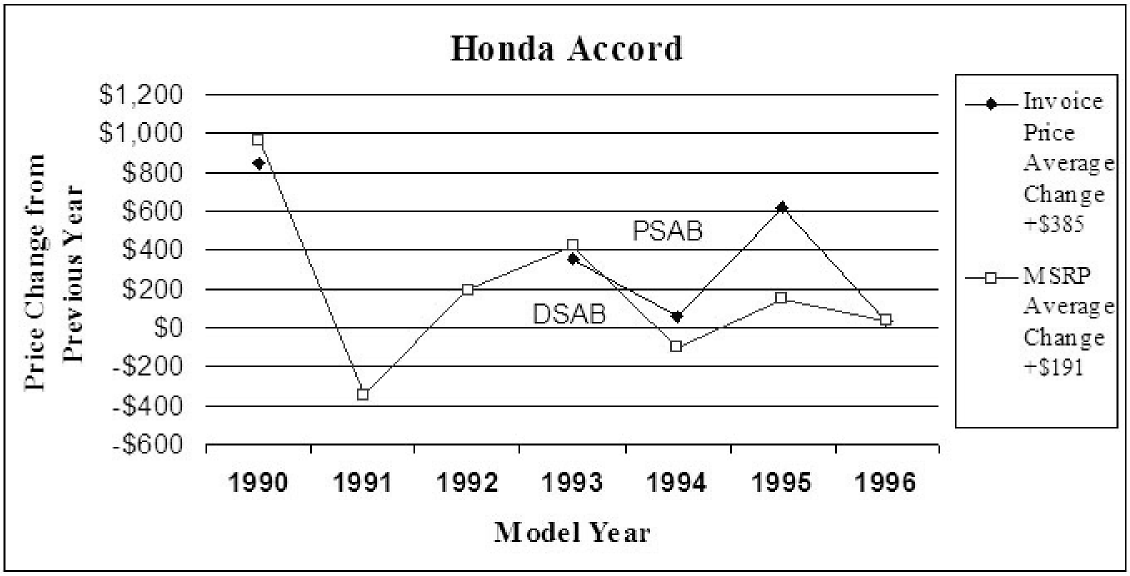
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		148,407	152,036	102,029	145,290	150,964	154,499	142,624	136,071
% of Make		25.9%	29.3%	18.7%	27.4%	30.0%	28.9%	29.2%	30.4%
Inv.	Current$	$13,229	$14,356	$14,741	$16,228	$17,444	$18,253	$19,019	$19,573
Inv.	2002$	$15,238	$16,290	$16,153	$17,353	$18,213	$18,427	$18,786	$19,005
MSRP	Current$	$15,425	$16,555	$17,080	$18,695	$19,935	$20,860	$21,735	$21,380
MSRP	2002$	$17,767	$18,785	$18,716	$19,991	$20,814	$21,059	$21,469	$20,760

LeSabre sales suffered in 1991, arguably because many of the domestic cars in its class had a standard driver airbag. The following year GM added the airbag, ABS and over $1000, and sales promptly rebounded.



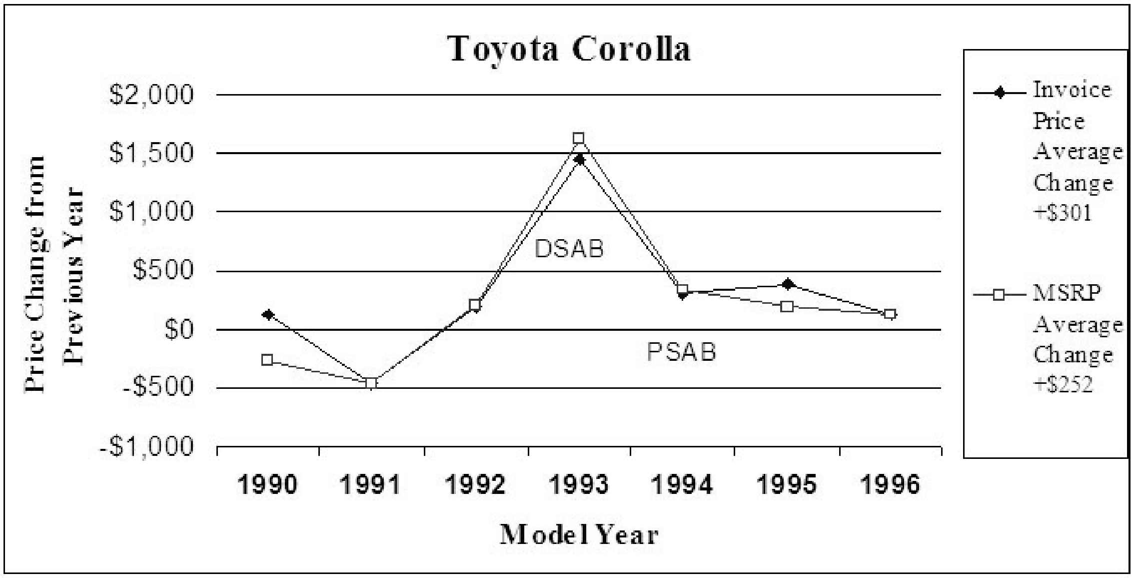
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		148,173	104,310	75,975	81,041	67,295	77,192	61,279	59,922
% of Make		22.7%	20.7%	17.0%	19.9%	18.7%	18.7%	15.7%	18.4%
Inv.	Current$	$13,200	$14,309	$14,840	$16,054	$17,106	$18,266	$19,492	$19,487
Inv.	2002$	$15,204	$16,237	$16,261	$17,167	$17,860	$18,441	$19,254	$18,922
MSRP	Current$	$15,295	$16,500	$17,195	$18,495	$19,549	$20,875	$20,410	$20,405
MSRP	2002$	$17,617	$18,723	$18,842	$19,777	$20,411	$21,075	$20,160	$19,813

The Oldsmobile Eighty-Eight was another GM product that fell dramatically in popularity during the period for reasons that are not well understood. GM offered a driver airbag for $723 up until the company included it as standard in 1993. Likewise, ABS were $787 before becoming standard in 1992. GM barely passed the cost of these devices onto the consumer probably due to the diminishing sales volume. GM would eventually terminate the Oldsmobile division in 2002.



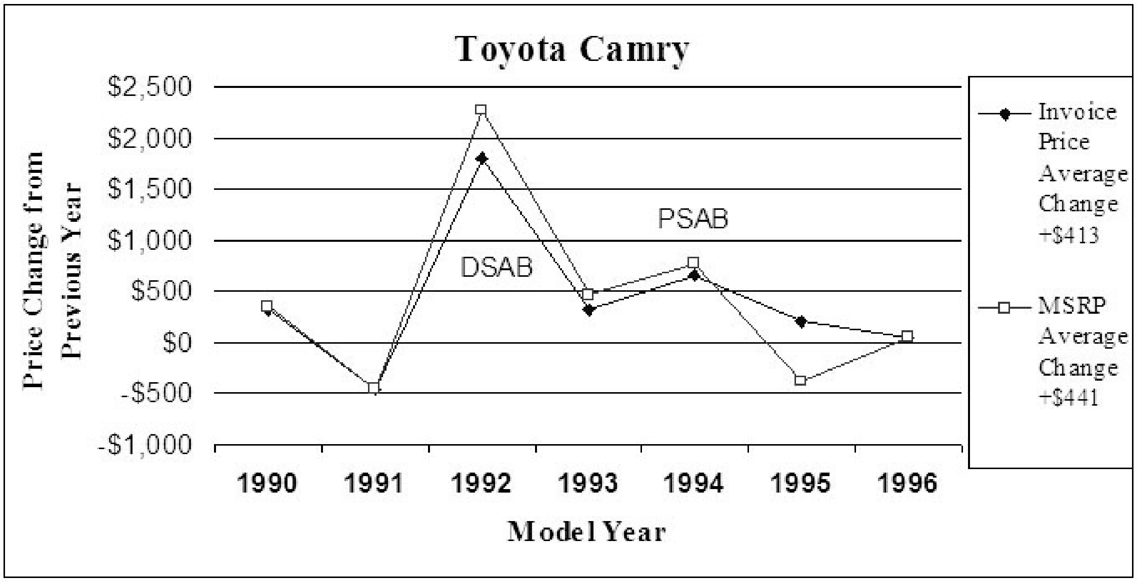
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		362,435	416,957	409,704	387,881	343,017	362,407	345,855	367,137
% of Make		55.4%	58.8%	60.5%	60.4%	55.2%	56.1%	53.5%	54.1%
Inv.	Current$	$9,719	$10,614	NA	$11,109	$11,718	$12,181	$13,078	$13,343
Inv.	2002$	$11,195	$12,044	NA	$11,879	$12,235	$12,297	$12,918	$12,956
MSRP	Current$	$11,570	$12,590	$12,725	$13,225	$13,950	$14,330	$14,800	$15,100
MSRP	2002$	$13,327	$14,286	$13,944	$14,142	$14,565	$14,467	$14,619	$14,662

The Accord, a perennial top-seller, received airbags in consecutive years with very little combined price upsurge. When Honda raised prices the most in this timeframe, inexplicably the company also sold the most Accords. Other than some styling changes, Honda did not fiddle much with its flagship car in the way of added equipment. The dealer price rose significantly in the year following the addition of the passenger airbag.



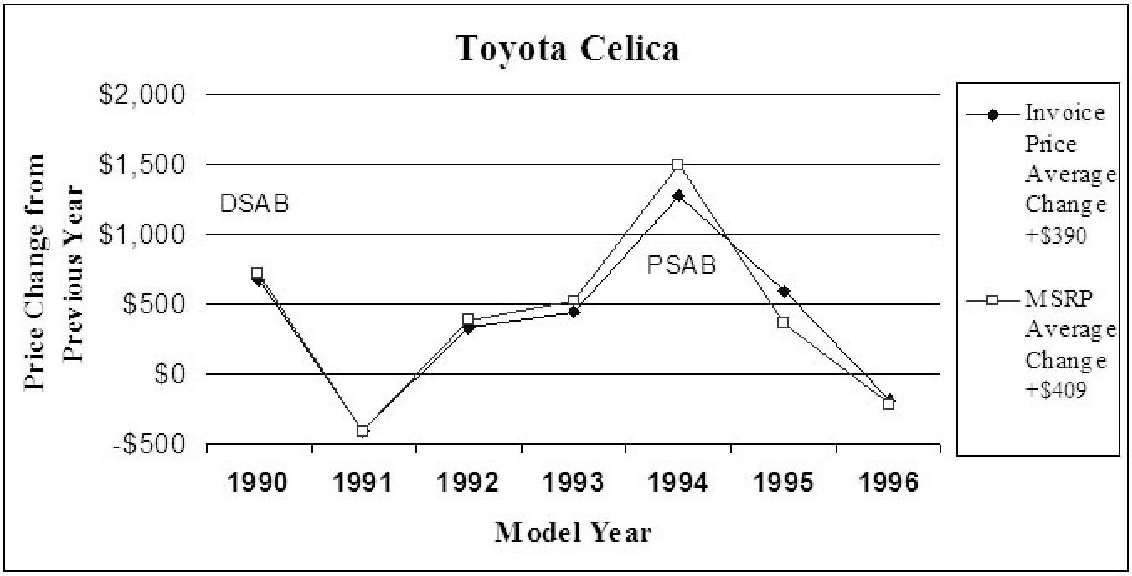
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		209,781	221,947	201,423	206,560	196,118	206,942	203,980	216,167
% of Make		30.3%	29.0%	27.1%	27.0%	25.7%	27.4%	26.3%	27.0%
Inv.	Current$	$7,909	$8,136	$8,008	$8,382	$9,966	$10,607	$11,236	$11,554
Inv.	2002$	$9,110	$9,232	$8,775	$8,963	$10,406	$10,708	$11,099	$11,219
MSRP	Current$	$9,198	$9,098	$8,998	$9,418	$11,198	$11,918	$12,378	$12,728
MSRP	2002$	$10,595	$10,324	$9,860	$10,071	$11,692	$12,032	$12,227	$12,359

An uncharacteristically large price hike and a styling overhaul accompanied the addition of an airbag in 1993. The relative price sensitivity of the Corolla can be spotted in the fall of sales during that year despite the styling and trim changes. The cost of the passenger airbag does not appear to have been passed onto the consumer during the first year or subsequent years.



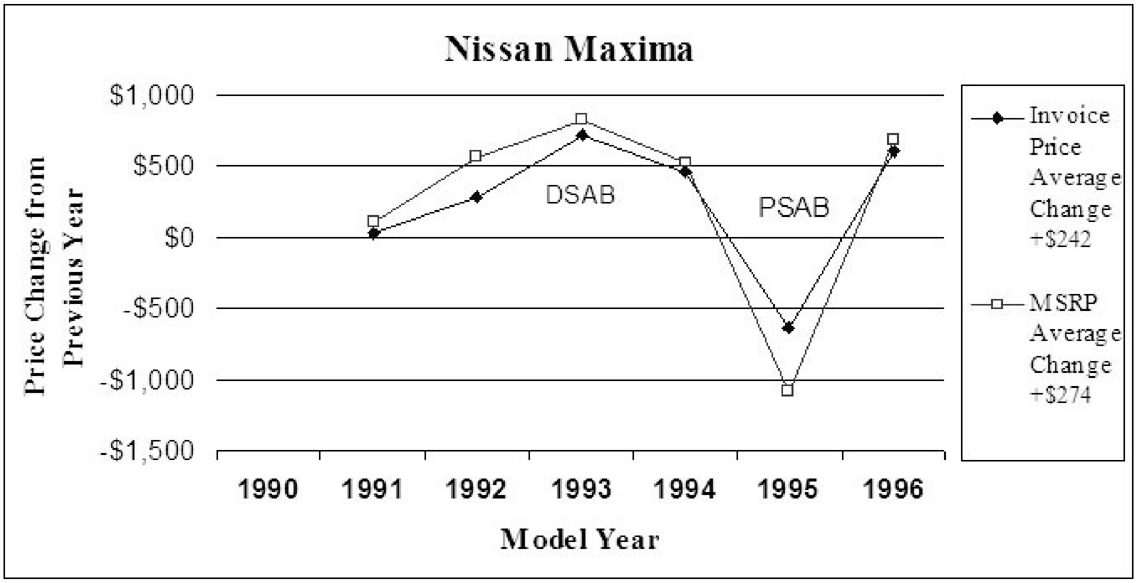
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		264,598	278,086	266,631	277,792	306,586	319,317	319,805	354,035
% of Make		38.2%	36.3%	35.9%	36.3%	40.1%	42.3%	41.2%	44.3%
Inv.	Current$	$9,880	$10,316	$10,275	$12,213	$12,809	$13,890	$14,401	$14,700
Inv.	2002$	$11,380	$11,706	$11,259	$13,060	$13,374	$14,023	$14,225	$14,274
MSRP	Current$	$11,448	$11,938	$11,948	$14,368	$15,158	$16,438	$16,418	$16,758
MSRP	2002$	$13,186	$13,546	$13,092	$15,364	$15,827	$16,595	$16,217	$16,272

The sales of Toyota's flagship car climbed steadily during this period. For the 1992 model year, the Camry underwent some changes including a driver airbag, more powerful engine, and some styling modifications. These changes were passed onto the consumer, but sales were not adversely affected by the steep rise in price. Part or all of the cost of the passenger airbag also appears to have been passed through during the year it was introduced.



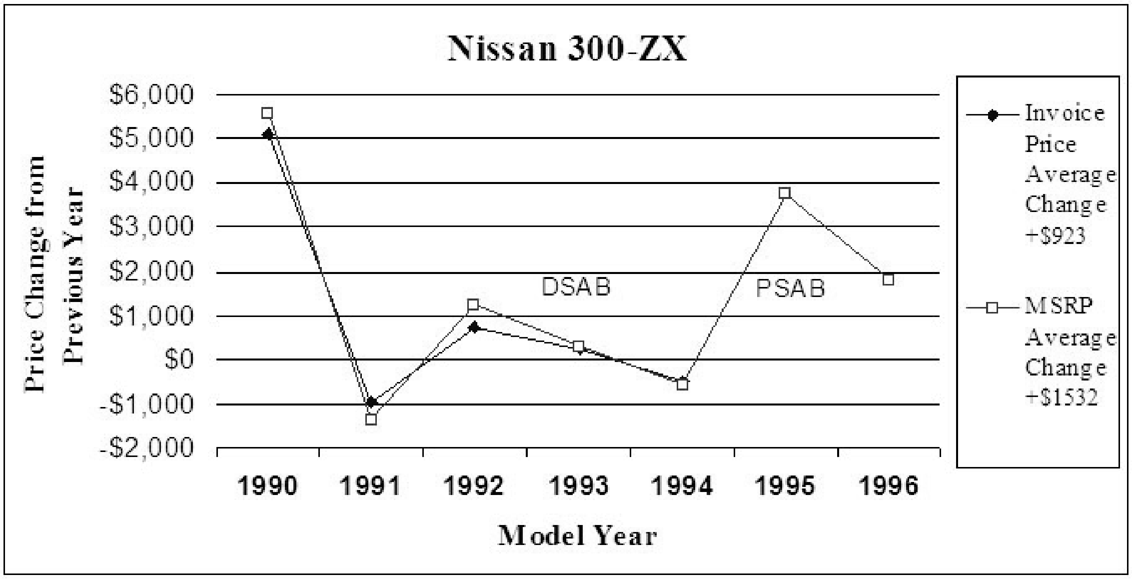
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		57,794	81,899	66,360	43,175	30,915	35,710	23,399	15,990
% of Make		8.3%	10.7%	8.9%	5.6%	4.0%	4.7%	3.0%	2.0%
Inv.	Current$	$10,096	$10,839	$10,857	$11,438	$12,139	$13,824	$14,727	$14,789
Inv.	2002$	$11,629	$12,299	$11,897	$12,231	$12,674	$13,956	$14,547	$14,360
MSRP	Current$	$11,808	$12,618	$12,698	$13,378	$14,198	$16,168	$16,888	$16,958
MSRP	2002$	$13,601	$14,318	$13,914	$14,305	$14,824	$16,323	$16,681	$16,466

In 1990, the Celica became the most affordable Japanese car with a standard airbag, the cost of which appears to have been passed on to the buyer. The sales rose dramatically as well signaling that the airbag and the higher price tag did not deter sales, and may have stimulated sales growth. When a passenger airbag was introduced for the 1994 model year, it was part of a redesigned and restyled sportier coupe evinced in the higher price tag.



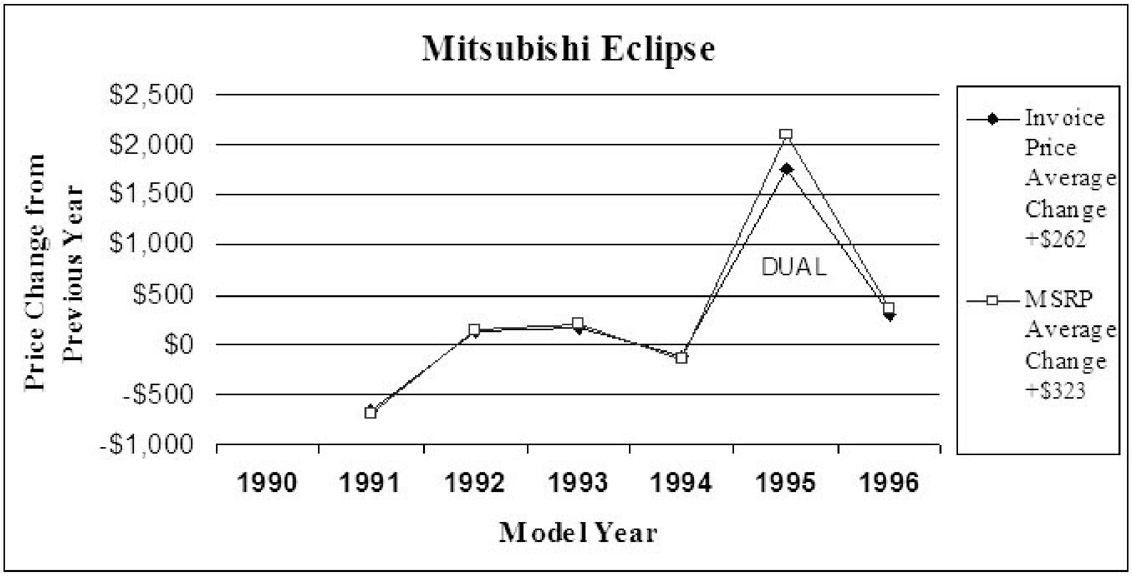
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		105,982	100,730	103,252	86,681	93,808	117,802	128,788	129,284
% of Make		20.8%	21.9%	24.4%	21.4%	19.8%	22.2%	24.1%	25.3%
Inv.	Current$	NA	$15,812	$16,403	$17,076	$18,172	$19,246	$19,021	$19,973
Inv.	2002$	NA	$17,942	$17,974	$18,260	$18,974	$19,430	$18,788	$19,394
MSRP	Current$	NA	$17,959	$18,699	$19,695	$20,960	$22,199	$21,599	$22,679
MSRP	2002$	NA	$20,378	$20,490	$21,060	$21,884	$22,411	$21,335	$22,021

A driver-side airbag was made standard on the Maxima in 1993 accompanied by a well above average price increase. The addition of the passenger-side airbag actually came with a significant price decrease. Some of the cost of the airbag system may have been absorbed, recouped the following year, or recovered by price increases in other models. For instance, in 1995 passenger airbags were also added to the Nissan 300 ZX along with a nearly $4,000 price increase. The price increase in 1996 for the 300 ZX was another $2,000.



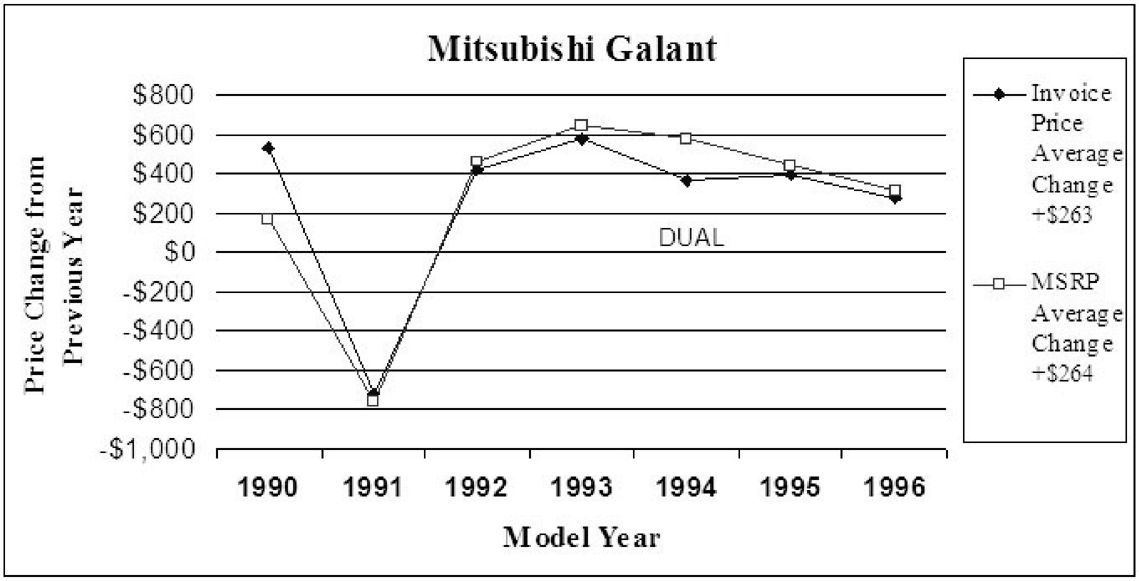
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		23,918	22,663	16,973	11,810	9,095	7,156	4,351	2,785
% of Make		4.7%	4.9%	4.0%	2.9%	1.9%	1.3%	0.8%	0.5%
Inv.	Current$	$18,940	$23,697	$23,669	$24,950	$25,786	$26,179	NA	$32,392
Inv.	2002$	$21,816	$26,889	$25,936	$26,679	$26,923	$26,429	NA	$31,453
MSRP	Current$	$22,299	$27,560	$27,300	$29,120	$30,095	$30,555	$35,009	$37,493
MSRP	2002$	$25,685	$31,273	$29,915	$31,138	$31,422	$30,847	$34,581	$36,406

The 300 ZX showed a great deal of price as well as sales volatility over this period. The average change in MSRP was $1,532, which included jumps of $5,500 and $4,000. The driver-side airbag was introduced with a very small price increase followed the next year by a price decline. When the passenger-side airbag became standard in 1995, the MSRP jumped by $4,000, but the sales continued to decline at the same steady pace. This 300 ZX was nearing the end of its lifecycle as the sales ebbed.



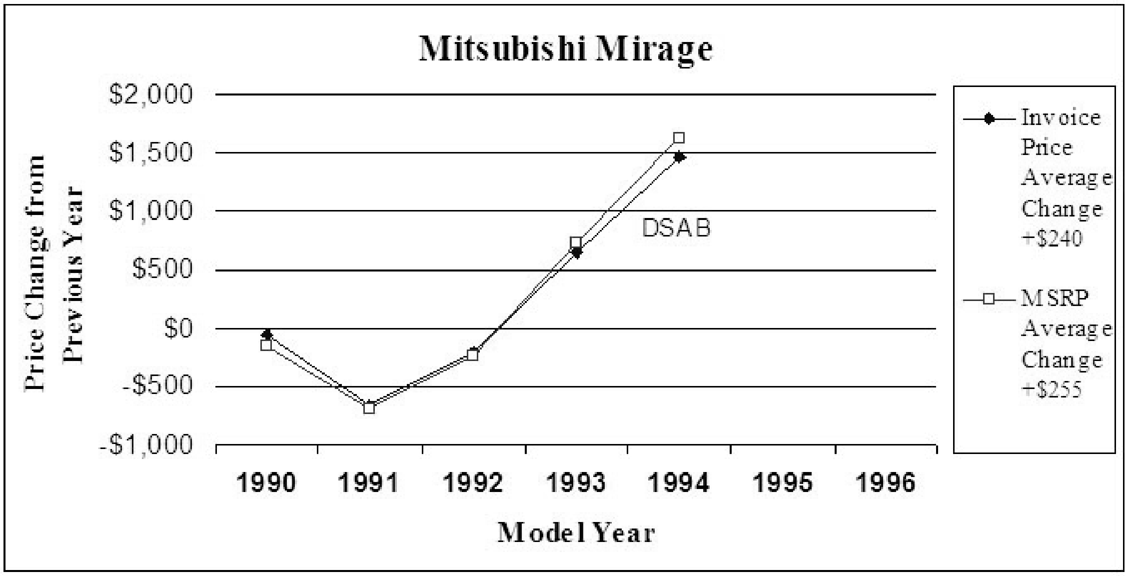
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		21,576	48,894	50,925	53,488	56,982	50,616	51,296	60,469
% of Make		23.7%	32.5%	33.6%	34.3%	35.3%	26.4%	26.6%	36.4%
Inv.	Current$	NA	$9,750	$9,501	$9,852	$10,252	$10,482	$12,497	$13,015
Inv.	2002$	NA	$11,063	$10,411	$10,535	$10,704	$10,582	$12,344	$12,638
MSRP	Current$	NA	$11,104	$10,859	$11,259	$11,719	$11,979	$14,359	$14,970
MSRP	2002$	NA	$12,600	$11,899	$12,039	$12,236	$12,094	$14,183	$14,536

The Eclipse showed virtually no change in price with the exception of the year when dual airbags were made standard on the sporty vehicle. This is a clear-cut example of an automaker attempting to recoup the cost of a regulated technology in the first year it was introduced. Sales remained strong despite the steep price hike, possibly because styling changes were also included in the vehicle's makeover.



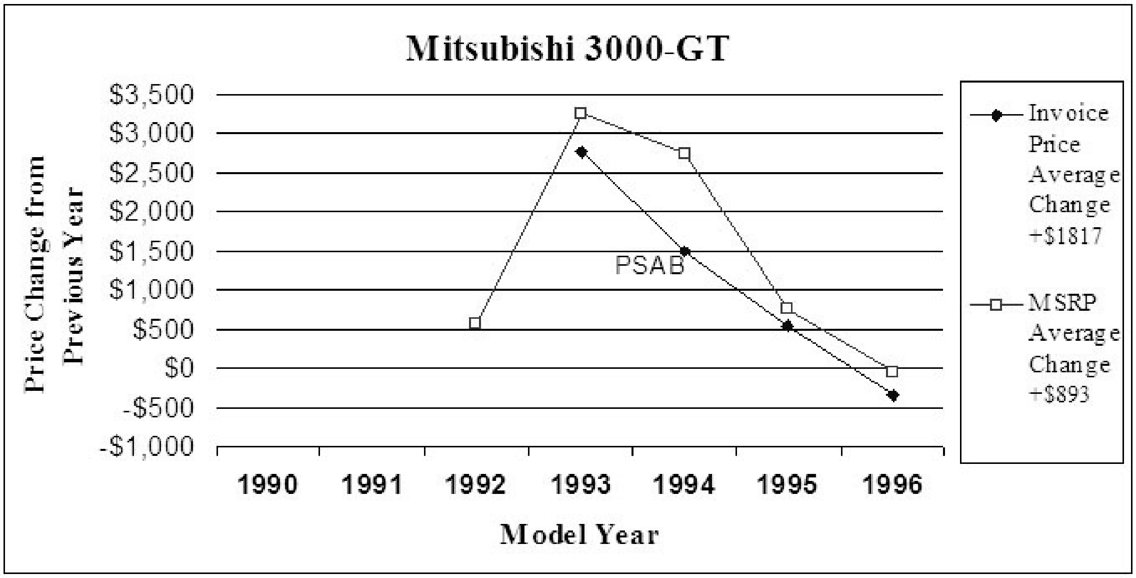
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		27,686	40,739	35,199	28,255	21,847	55,315	62,882	66,373
% of Make		30.4%	27.1%	23.2%	18.1%	13.5%	28.9%	32.6%	40.0%
Inv.	Current$	$9,595	$10,202	$9,909	$10,545	$11,356	$12,104	$12,771	$13,275
Inv.	2002$	$11,052	$11,576	$10,858	$11,276	$11,857	$12,220	$12,615	$12,890
MSRP	Current$	$10,971	$11,287	$10,999	$11,699	$12,599	$13,600	$14,349	$14,920
MSRP	2002$	$12,637	$12,807	$12,052	$12,510	$13,155	$13,730	$14,174	$14,487

Mitsubishi may have eaten some of the cost when dual airbags were made standard in 1994, but sales also rose by more than 2 ½ times, assisted by the presence of the new safety system, as well as, styling changes and a more powerful engine that may have resonated with consumers.



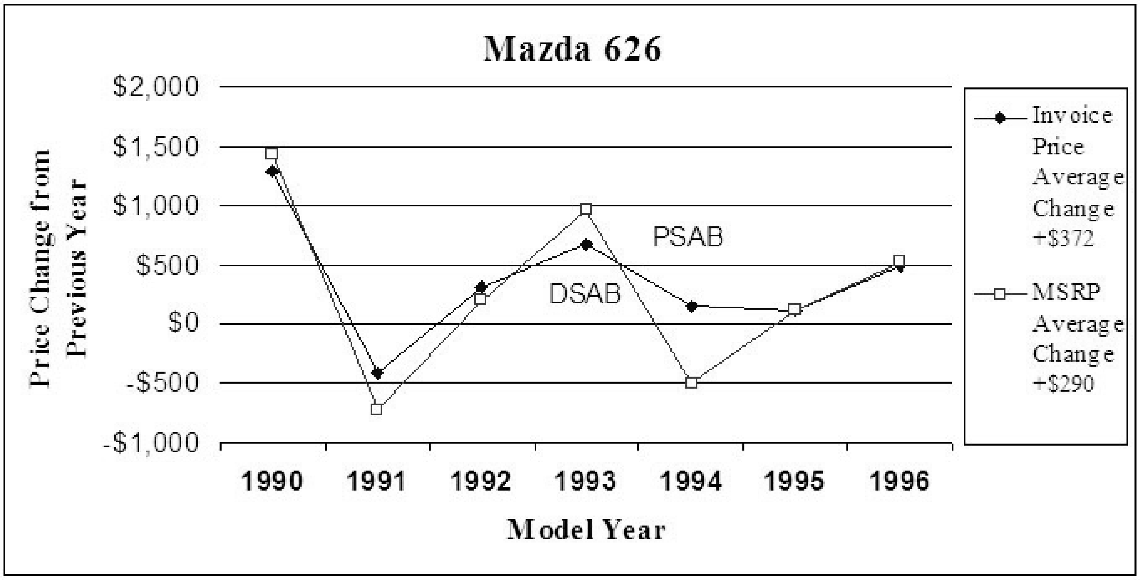
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		18,979	53,692	40,438	21,487	24,982	37,452	51,702	25,875
% of Make		20.8%	35.7%	26.7%	13.8%	15.5%	19.6%	26.8%	15.6%
Inv.	Current$	$7,930	$8,009	$7,692	$7,692	$8,496	$10,237	NA	NA
Inv.	2002$	$9,134	$9,088	$8,429	$8,225	$8,871	$10,335	NA	NA
MSRP	Current$	$8,859	$8,857	$8,549	$8,539	$9,439	$11,369	NA	NA
MSRP	2002$	$10,204	$10,050	$9,368	$9,131	$9,855	$11,478	NA	NA

Mitsubishi made driver-side airbags standard on MY1994 Mirages together with a $1,500 price increase. Sales bounced back for the 1994 and 1995 models despite the price increase.



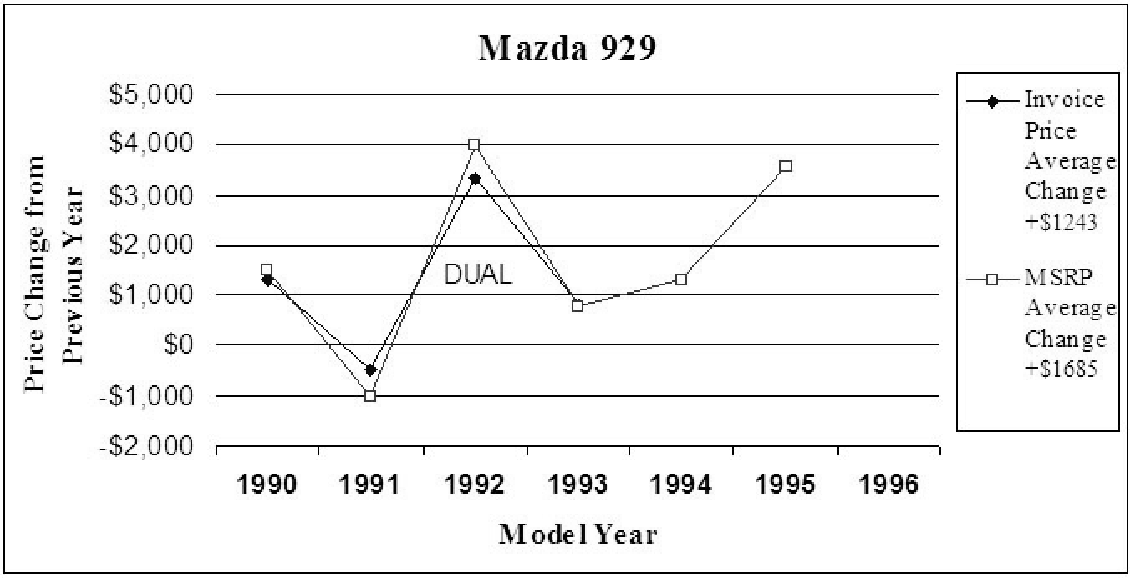
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		-	25	10,575	11,313	13,246	15,353	11,158	8,203
% of Make		0.0%	0.0%	7.0%	7.3%	8.2%	8.0%	5.8%	4.9%
Inv.	Current$	NA	NA	NA	$17,049	$20,111	$22,286	$23,317	$23,372
Inv.	2002$	NA	NA	NA	$18,231	$20,998	$22,499	$23,032	$22,694
MSRP	Current$	NA	NA	$19,059	$20,049	$23,659	$27,175	$28,540	$28,991
MSRP	2002$	NA	NA	$20,884	$21,439	$24,703	$27,435	$28,191	$28,150

Large MSRP increases, totaling about $6,000, were made the year previous to and the year of the introduction of a passenger-side airbag. Sales peaked during these two years when prices grew most rapidly. Part of Mitsubishi's airbag cost recovery strategy may have involved very large price hikes on price-neutral models such as the 3000 GT, and more stability on the more price-sensitive models such as the Galant.



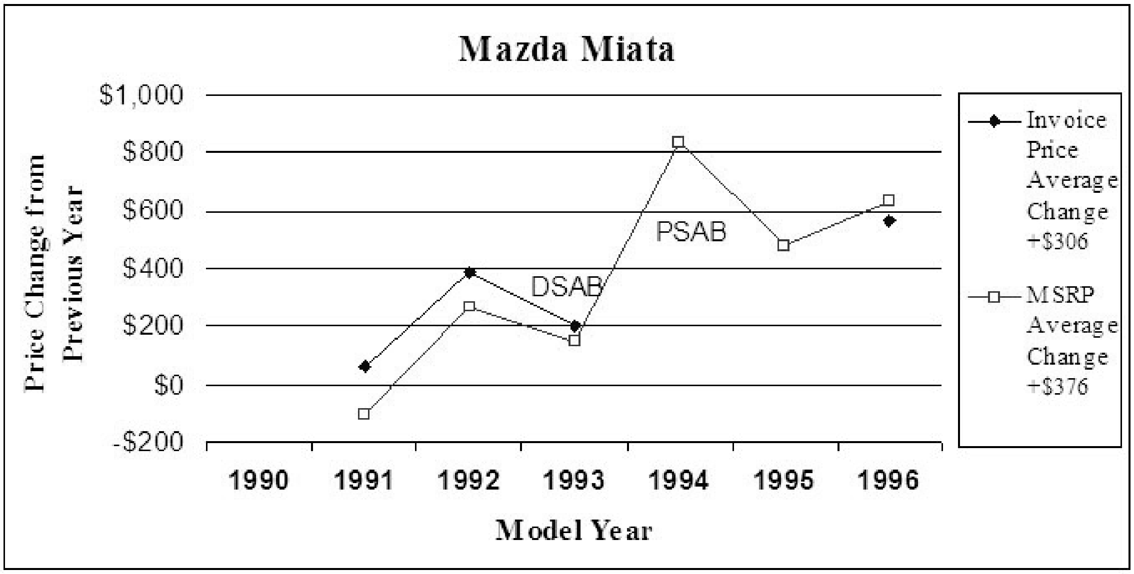
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		57,495	64,420	68,496	50,320	66,160	81,210	99,086	81,638
% of Make		25.1%	28.1%	30.7%	21.2%	26.4%	28.7%	40.0%	42.8%
Inv.	Current$	$9,774	$11,056	$11,063	$11,627	$12,557	$13,134	$13,540	$14,277
Inv.	2002$	$11,258	$12,545	$12,123	$12,433	$13,111	$13,260	$13,374	$13,863
MSRP	Current$	$11,299	$12,738	$12,529	$13,025	$14,255	$14,255	$14,695	$15,495
MSRP	2002$	$13,015	$14,454	$13,729	$13,928	$14,884	$14,391	$14,515	$15,046

The 626 also exhibits substantial price volatility. When driver-side airbags were made standard there was a $1,000 rise in MSRP, but the following year when passenger-side airbags were introduced, MSRP declined by $500, while inventory price increased slightly. There are clearly corporate objectives related to profit maximization and market share preservation of the company’s most popular passenger car that inform pricing policy more than straight cost recovery from airbags.



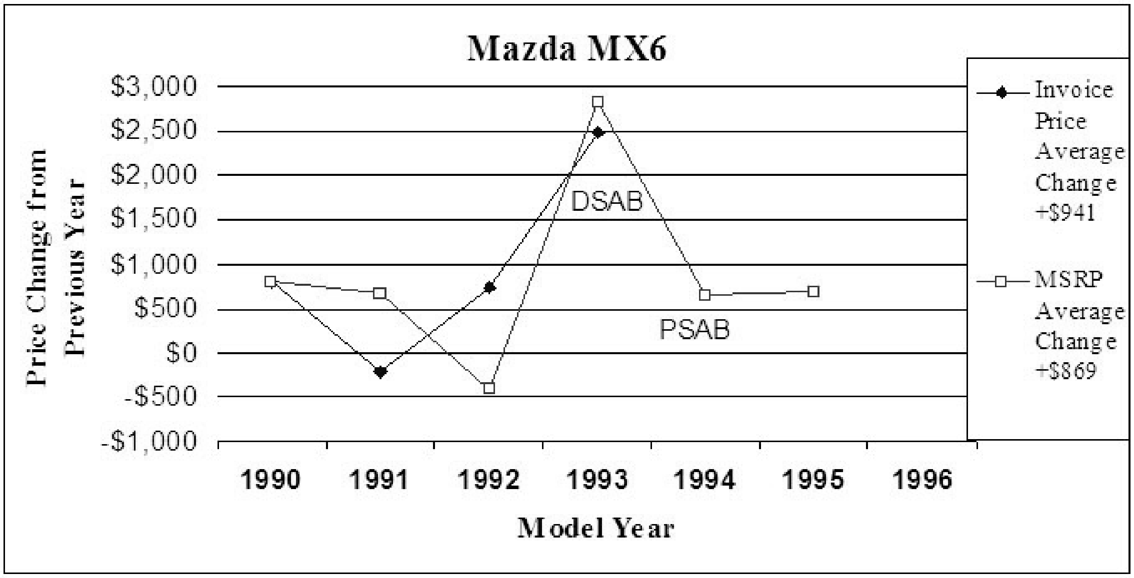
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		20,794	16,938	14,151	21,398	18,122	13,003	5,153	1,627
% of Make		9.1%	7.4%	6.3%	9.0%	7.2%	4.6%	2.1%	0.9%
Inv.	Current$	$18,194	$19,618	$19,880	$23,492	$24,835	NA	$30,802	NA
Inv.	2002$	$20,957	$22,261	$21,784	$25,120	$25,930	NA	$30,425	NA
MSRP	Current$	$21,920	$23,579	$23,500	$27,800	$29,200	$31,500	$35,795	NA
MSRP	2002$	$25,248	$26,755	$25,751	$29,727	$30,488	$31,801	$35,357	NA

The 929 is Mazda's luxury sedan and is not subject to the degree of price sensitivity of the 626, MX6, or 323. For this reason, dual airbags were accompanied by a $4,000 increase in MSRP. The inventory cost only grew by about $3,300, which gave dealers room to deal if consumers reacted adversely to the price increase. Sales peaked during this year, which may be due to the inclusion of an airbag system, or possibly because consumers in this market segment associate price positively with added features and prestige.



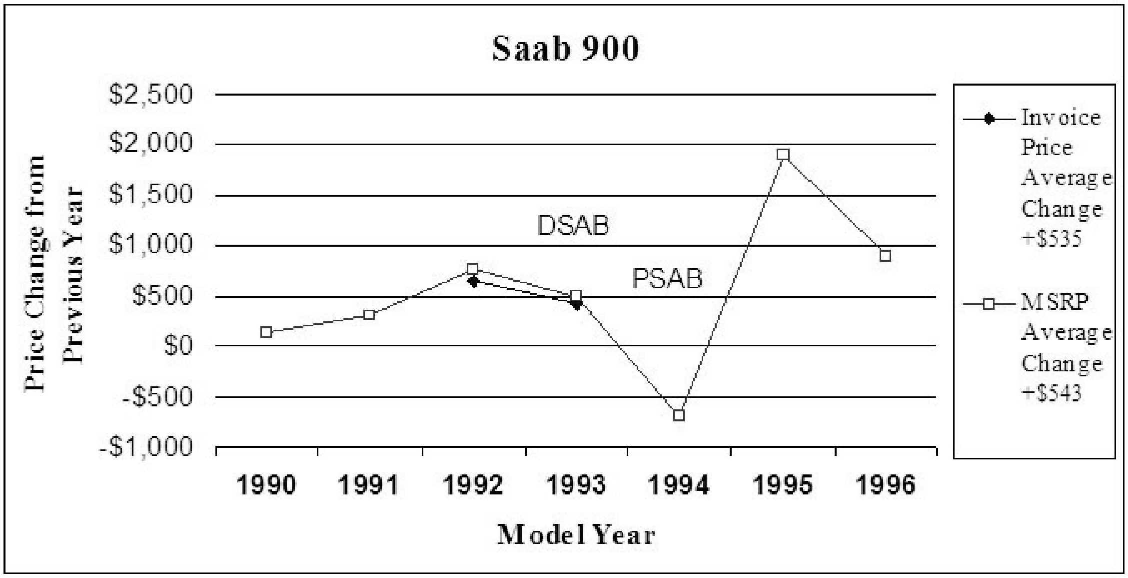
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		13,525	38,133	34,610	24,847	22,350	22,705	20,790	17,984
% of Make		5.9%	16.6%	15.5%	10.4%	8.9%	8.0%	8.4%	9.4%
Inv.	Current$	NA	$11,963	$12,449	$13,119	$13,632	NA	$15,768	$16,624
Inv.	2002$	NA	$13,575	$13,641	$14,028	$14,233	NA	$15,575	$16,142
MSRP	Current$	NA	$13,800	$14,200	$14,800	$15,300	$16,650	$17,500	$18,450
MSRP	2002$	NA	$15,659	$15,560	$15,826	$15,975	$16,809	$17,286	$17,915

The Miata is a budget two-seater. When driver-side airbags were made standard for the 1993 model year, there was only a small price increase. The following year when a passenger-side airbag was added, there was a significant price increase of $800, which could presumably recover the entire airbag system cost.



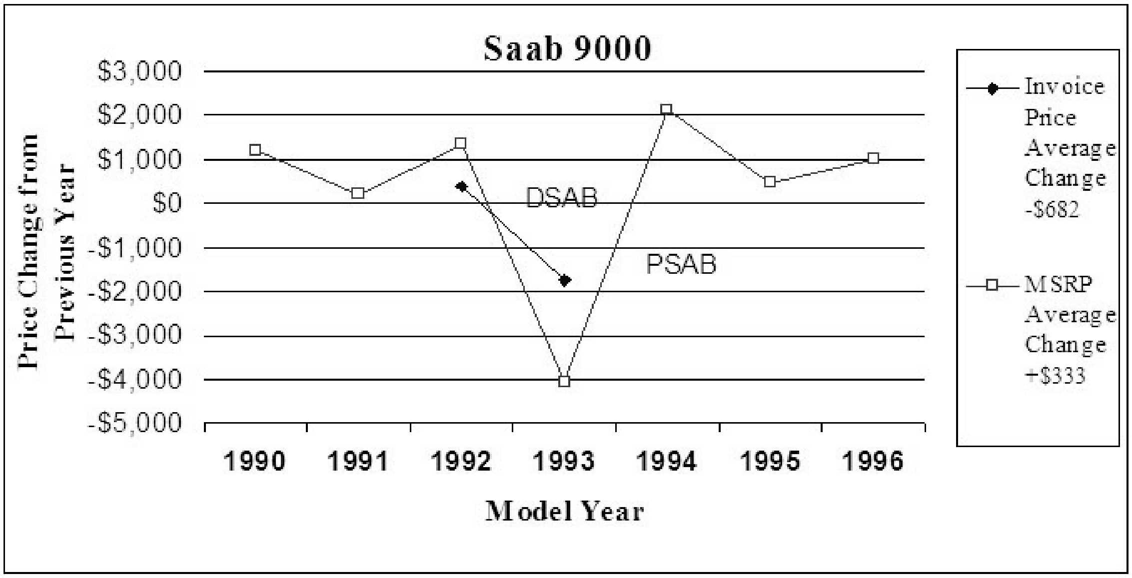
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		43,522	30,435	25,402	22,020	29,676	22,740	17,883	7,957
% of Make		19.0%	13.3%	11.4%	9.3%	11.8%	8.0%	7.2%	4.2%
Inv.	Current$	$9,746	$10,594	$10,765	$11,707	$14,358	NA	$16,546	NA
Inv.	2002$	$11,226	$12,021	$11,796	$12,518	$14,991	NA	$16,344	NA
MSRP	Current$	$11,399	$12,279	$13,329	$13,265	$16,300	$17,495	$18,573	NA
MSRP	2002$	$13,130	$13,933	$14,606	$14,184	$17,019	$17,662	$18,346	NA

Apparently, the MX6 does not exhibit as much price sensitivity as most cars in its market segment. When driver-side airbags were introduced alongside a more powerful engine and new styling features, the price skyrocketed by nearly $3,000. Sales increased as well. For some reason, the MX6 could absorb the added cost, which helped Mazda partially recoup the costs due to airbags from other lines as well.



Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		24,536	17,458	16,499	15,785	11,630	14,236	20,055	21,283
% of Make		70.9%	67.6%	62.4%	61.6%	57.4%	68.7%	77.0%	76.6%
Inv.	Current$	$14,800	NA	$15,899	$16,896	$17,711	NA	$20,687	NA
Inv.	2002$	$17,047	NA	$17,422	$18,067	$18,492	NA	$20,434	NA
MSRP	Current$	$17,515	$17,898	$18,815	$19,995	$20,960	$20,990	$23,375	$24,695
MSRP	2002$	$20,175	$20,309	$20,617	$21,381	$21,884	$21,191	$23,089	$23,979

The Saab 900 is more price sensitive than its more luxurious counterpart, the 9000. A price drop of $500 for the 900 accompanied the passenger-side airbag, but in the case of the 9000, there was a $2000 price increase. The addition of the driver-side airbag the previous year saw the opposite dynamic – the 9000 had a large price drop while the 900 was given a significant price increase. Saab did this price jockeying to maximize sales and profits, while at the same time recouping compliance costs.



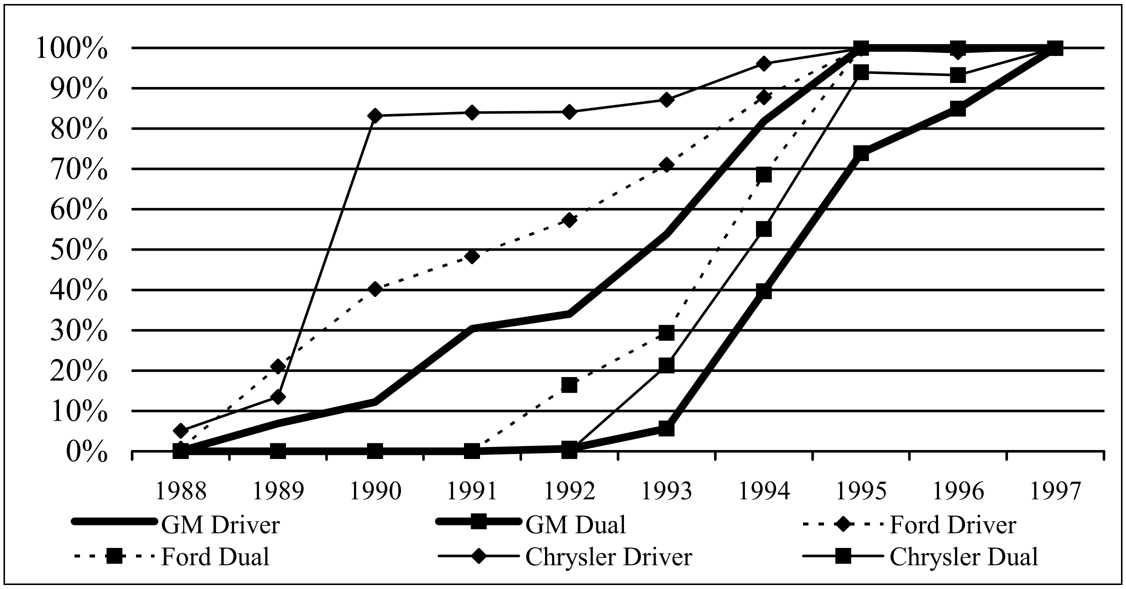
Year		1989	1990	1991	1992	1993	1994	1995	1996
Sales		10,089	8,351	9,951	9,838	8,637	6,498	5,999	6,501
% of Make		29.1%	32.4%	37.6%	38.4%	42.6%	31.3%	23.0%	23.4%
Inv.	Current$	$20,167	NA	$22,325	$23,235	$22,123	NA	$26,338	NA
Inv.	2002$	$23,229	NA	$24,463	$24,846	$23,099	NA	$26,016	NA
MSRP	Current$	$24,445	$25,878	$26,995	$28,905	$25,725	$28,725	$29,845	$31,395
MSRP	2002$	$28,157	$29,364	$29,580	$30,909	$26,860	$29,000	$29,480	$30,485

The sales of the 9000 lagged during this period as it awaited a styling and performance makeover. The relative low demand for the 9000 kept price changes to a minimum and as a result it had a smaller average MSRP change than the 900. The price increases during the year the passenger-side airbag was introduced and the two following years indicates that Saab may have been recovering costs that resulted from compliance.

APPENDIX B: DETAILED AIRBAG AND ABS INSTALLATION RATES

Note: All of the below graphs represent the percentage of passenger cars sold in the U.S. with the specified factory installed attribute. The source for these data is *Ward's Automotive Yearbook.*

Big 3 Airbag Installation Rates



Japanese Big 3 Airbag Installation Rates

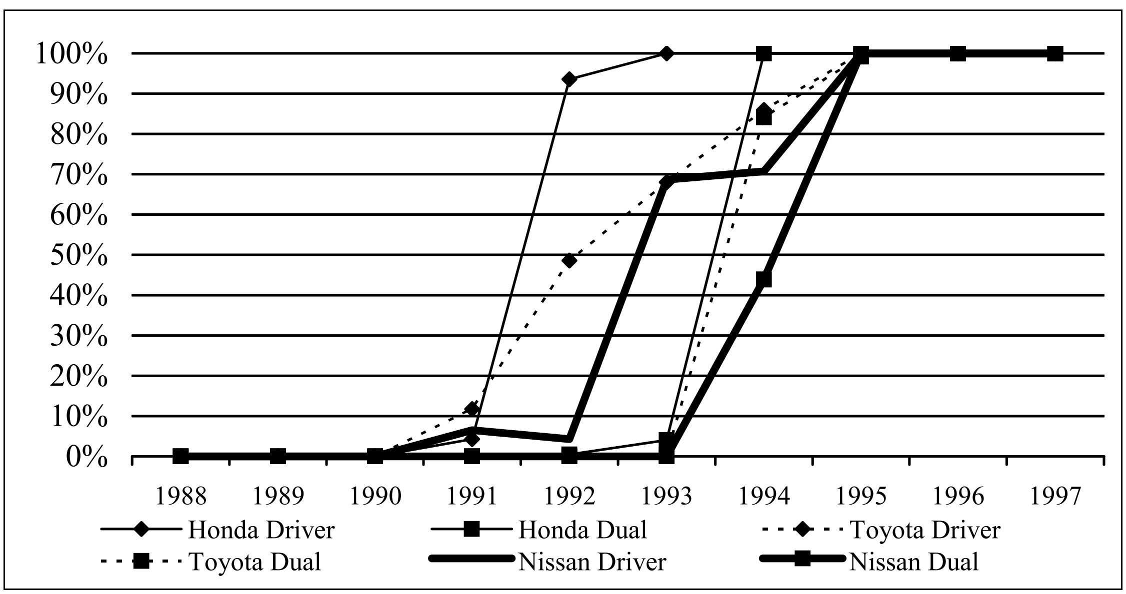
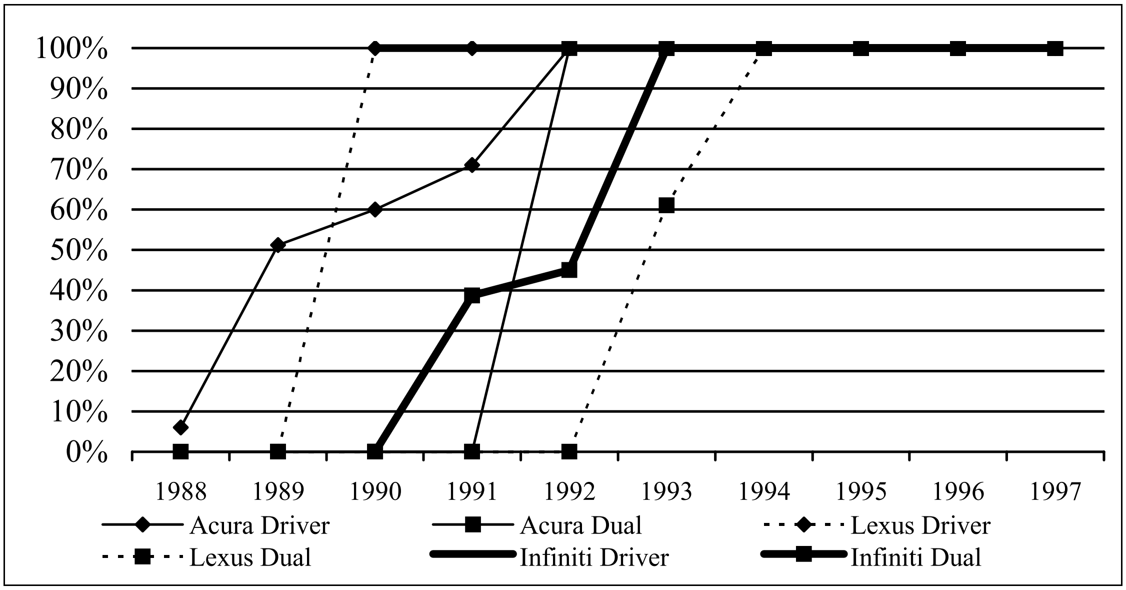
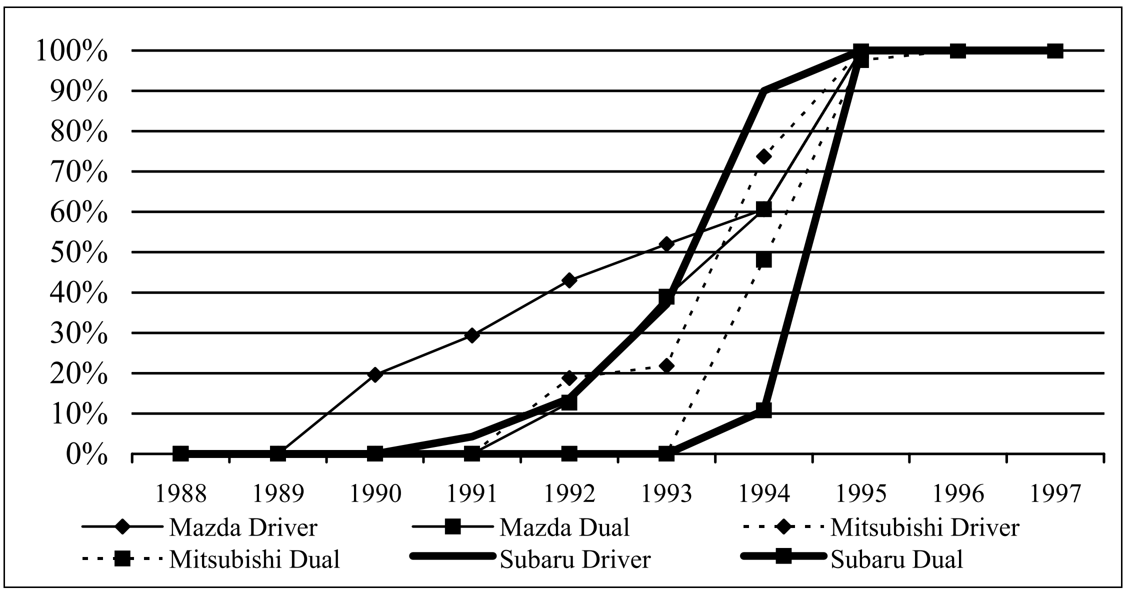


Figure Note: Does not include luxury divisions of the Japanese automakers (i.e. Acura, Lexus, Infiniti)

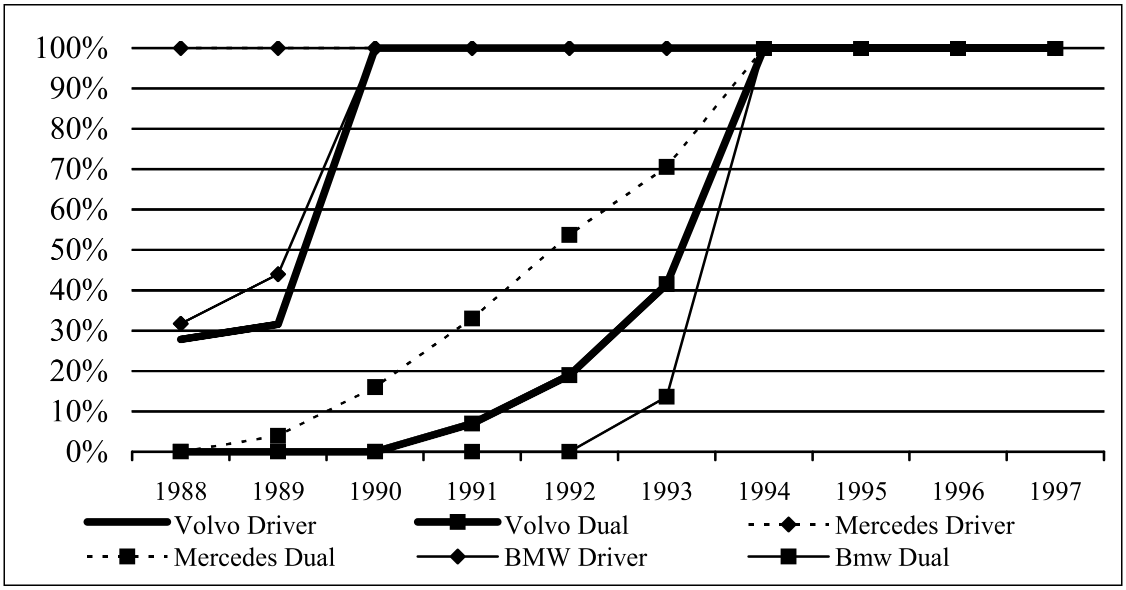
Japanese Big 3 Luxury Divisions Airbag Installation Rates



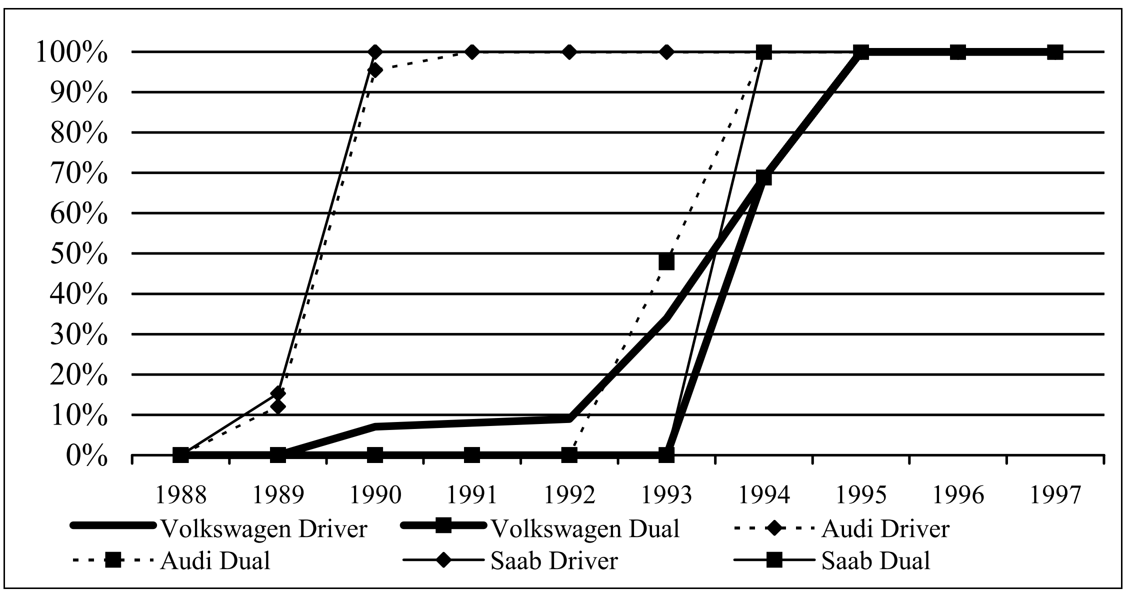
Other Japanese Automaker Airbag Installation Rates



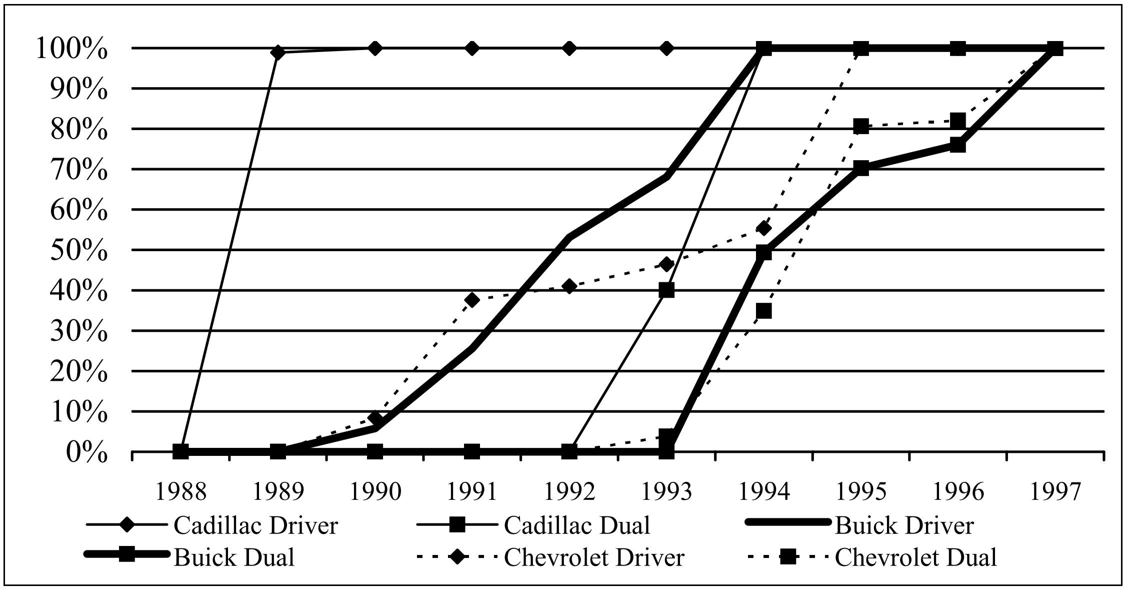
Luxury European Automaker Airbag Installation Rates



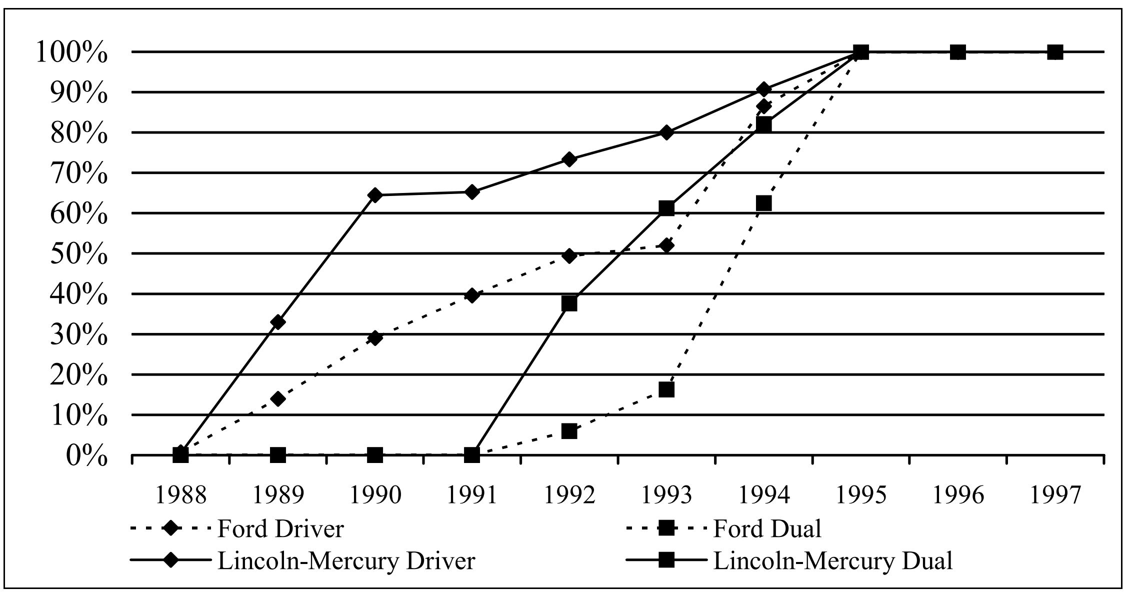
Additional European Automaker Airbag Installation Rates



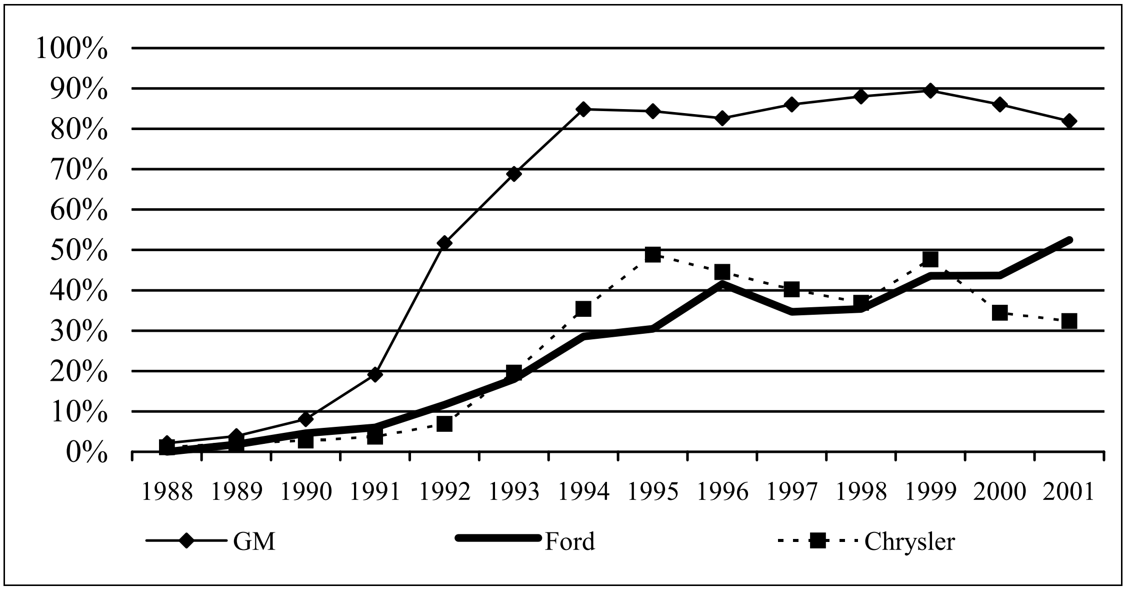
GM Airbag Installation Rates by Division



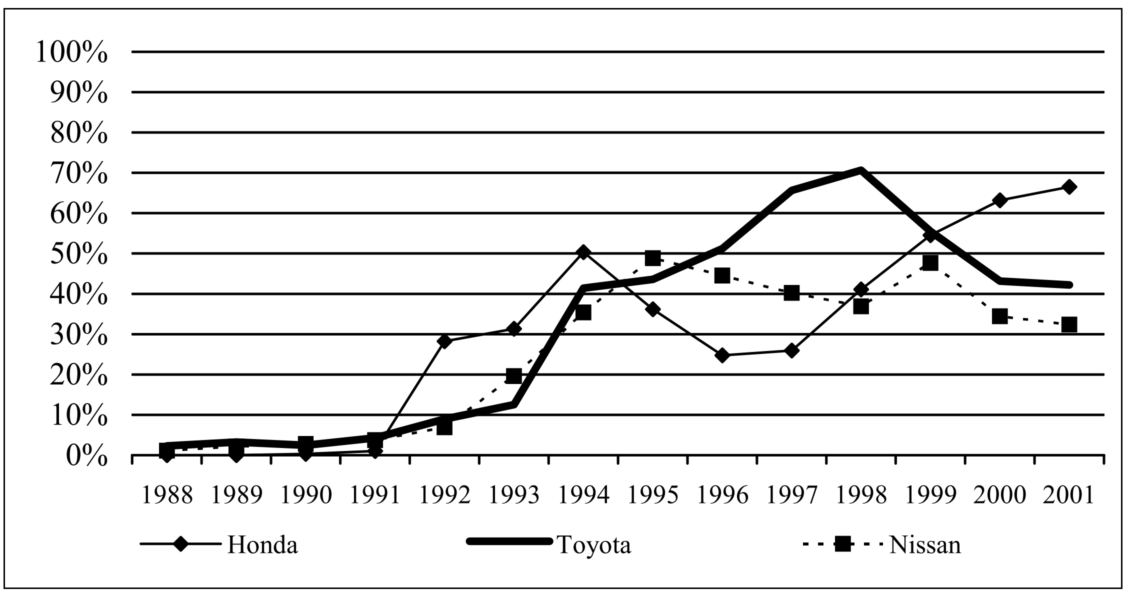
Ford Airbag Installation Rates by Division



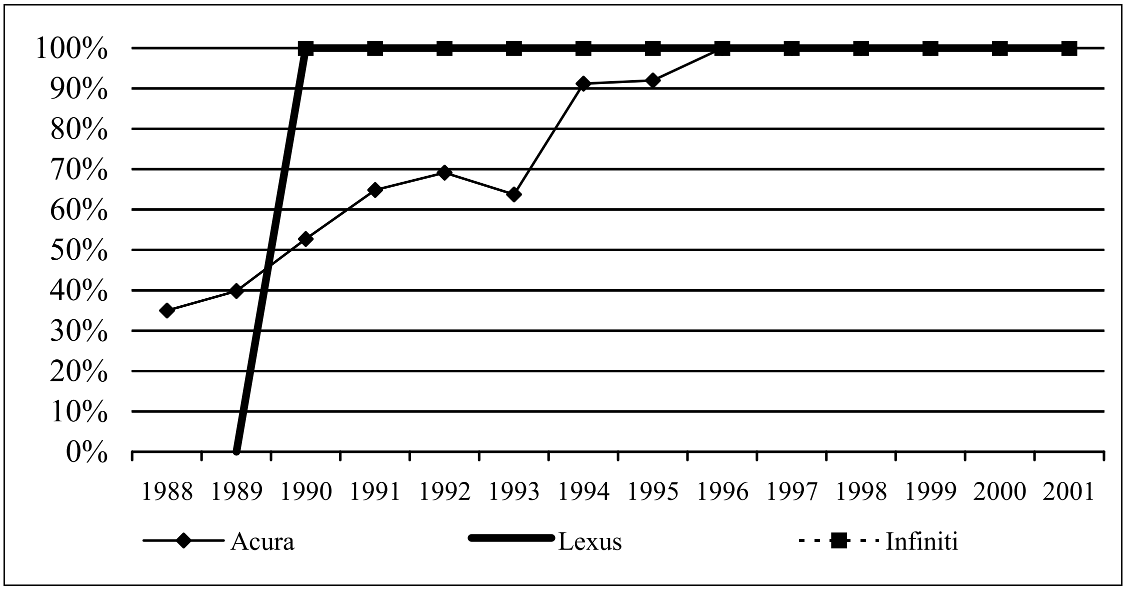
Big 3 ABS Installation Rates



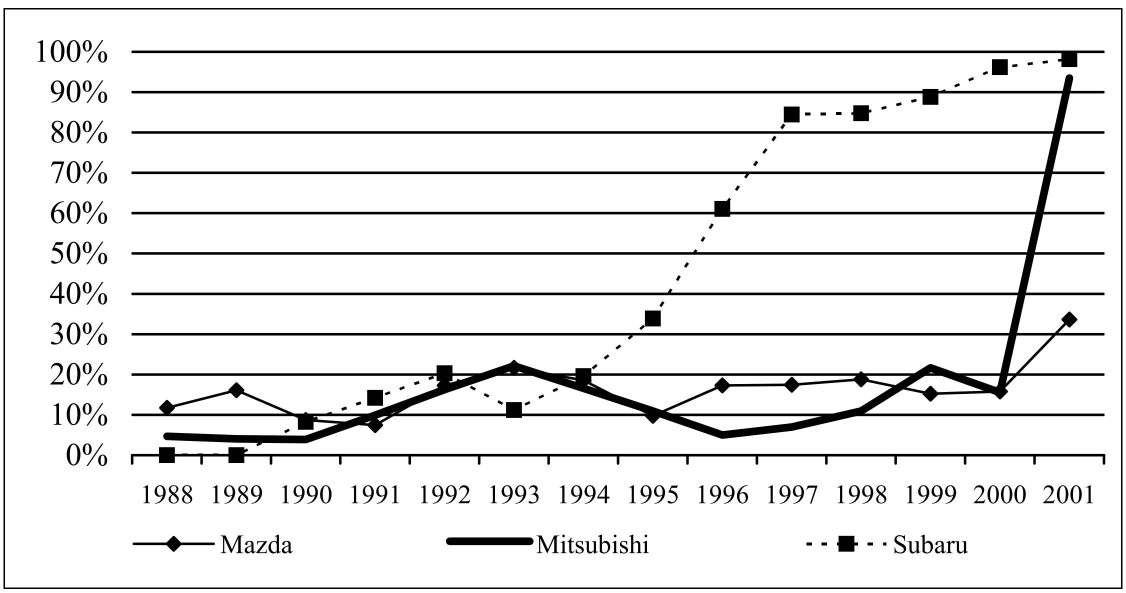
Japanese Big 3 ABS Installation Rates



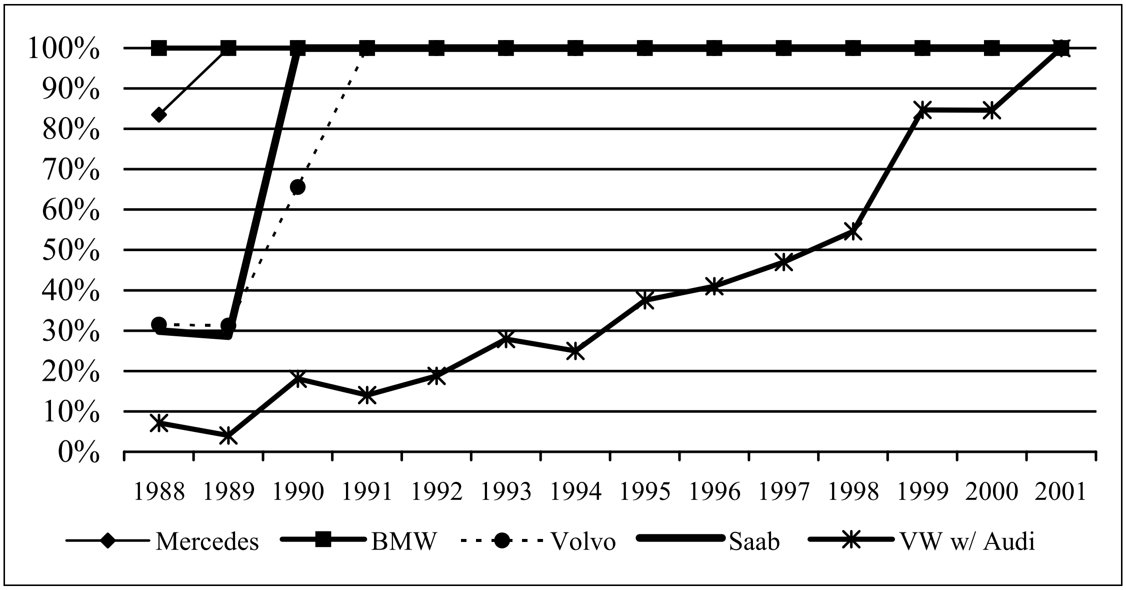
Japanese Luxury Big 3 ABS Installation Rates



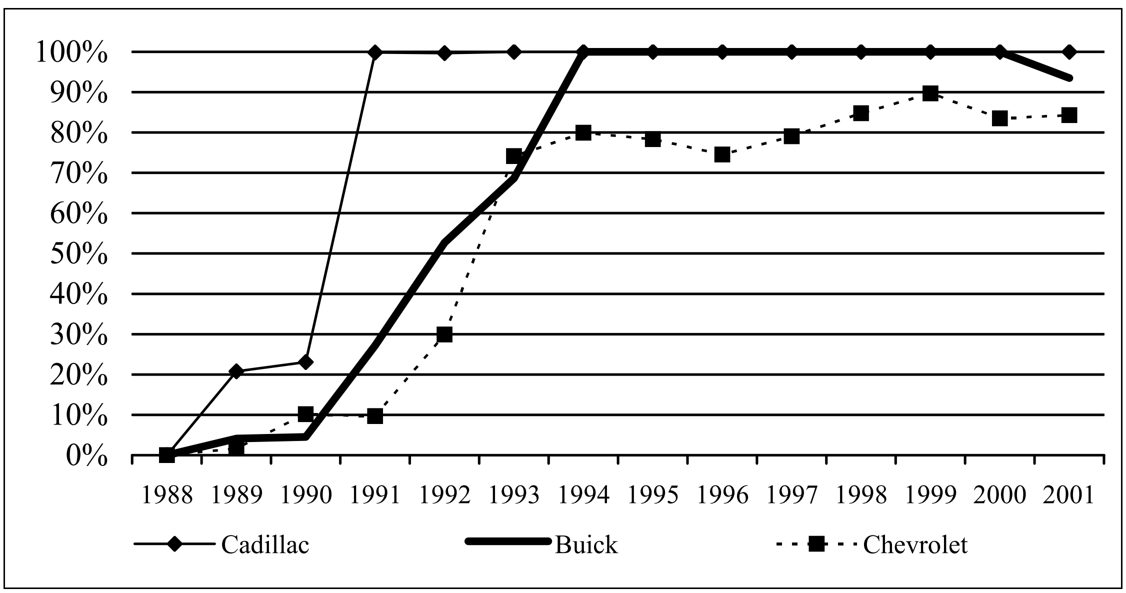
Other Japanese Automaker ABS Installation Rates



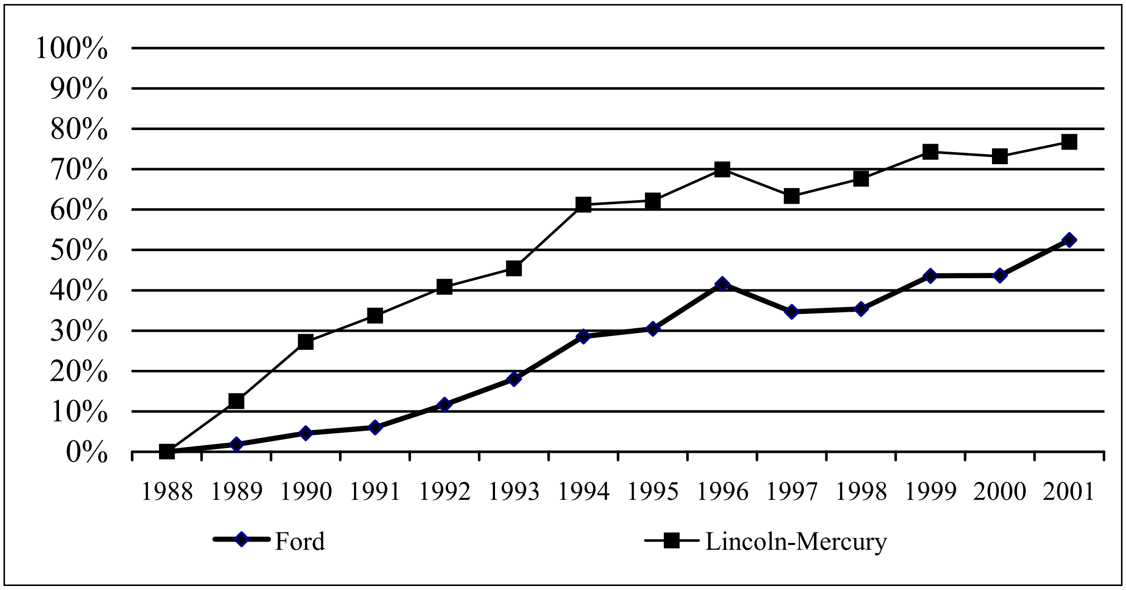
European Automaker ABS Installation Rates



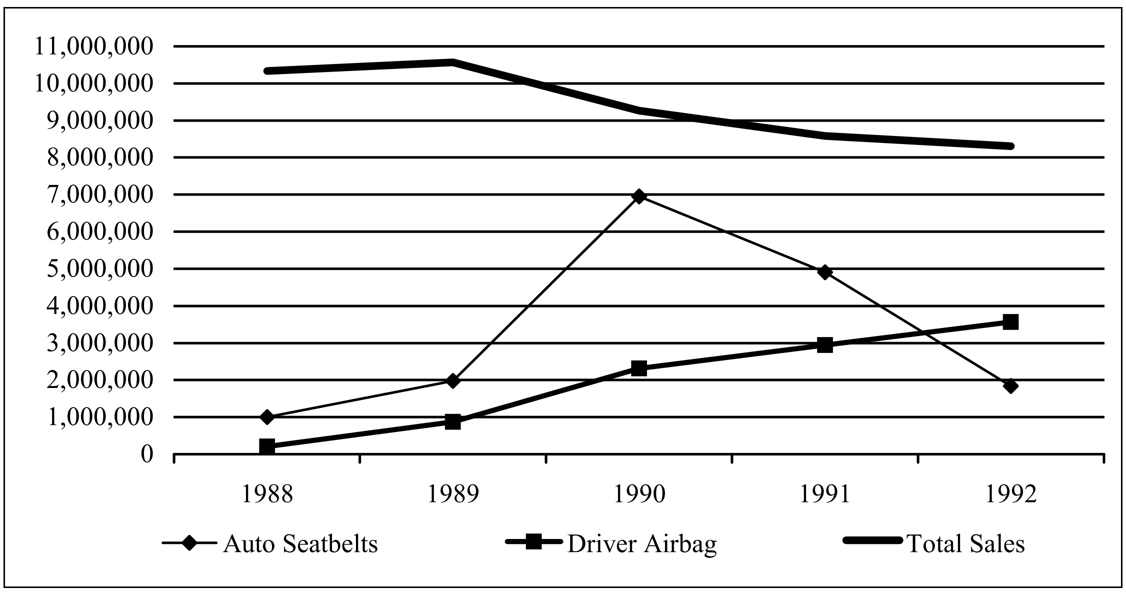
GM ABS Installation Rates by Division



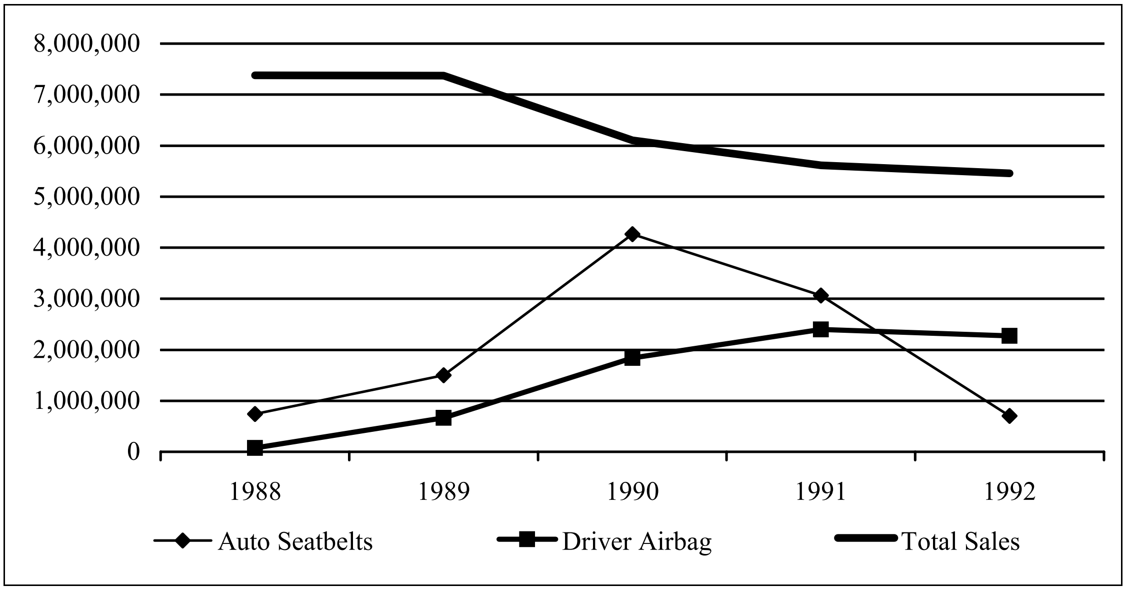
Ford ABS Installation Rates by Division



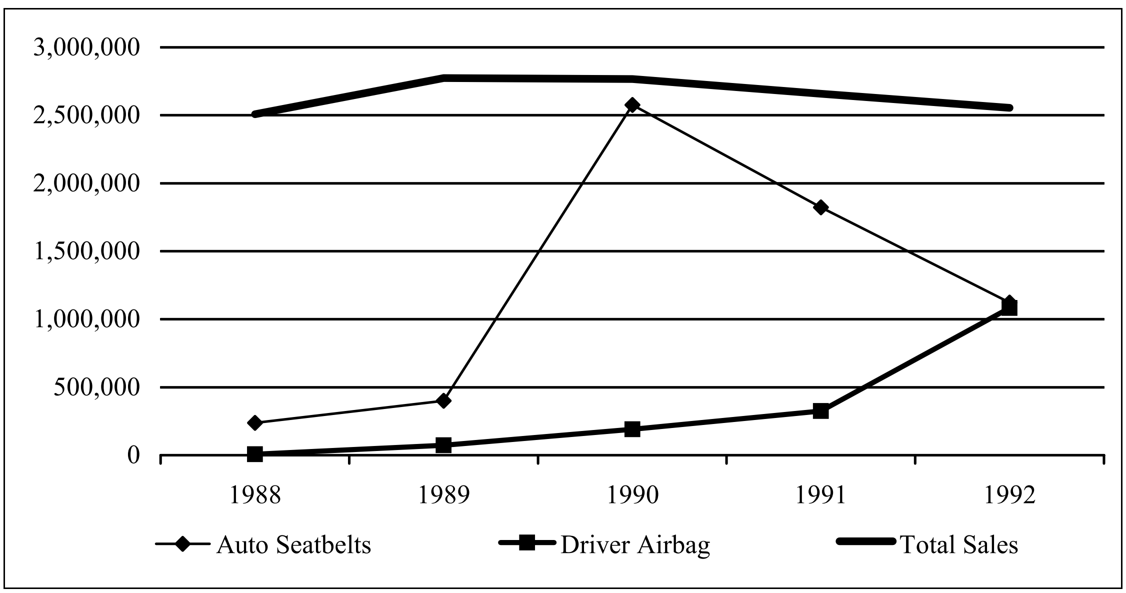
Passive Restraint Installation Trends and Total Passenger Car Sales (All Cars)



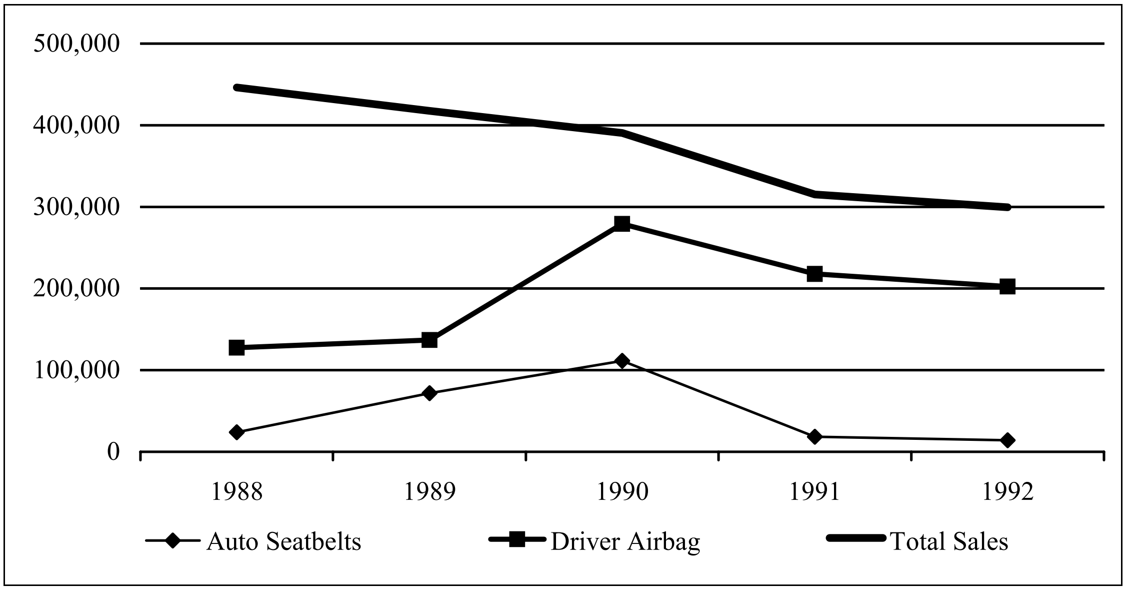
Passive Restraint Installation Trends and Total Passenger Car Sales (Big 3)



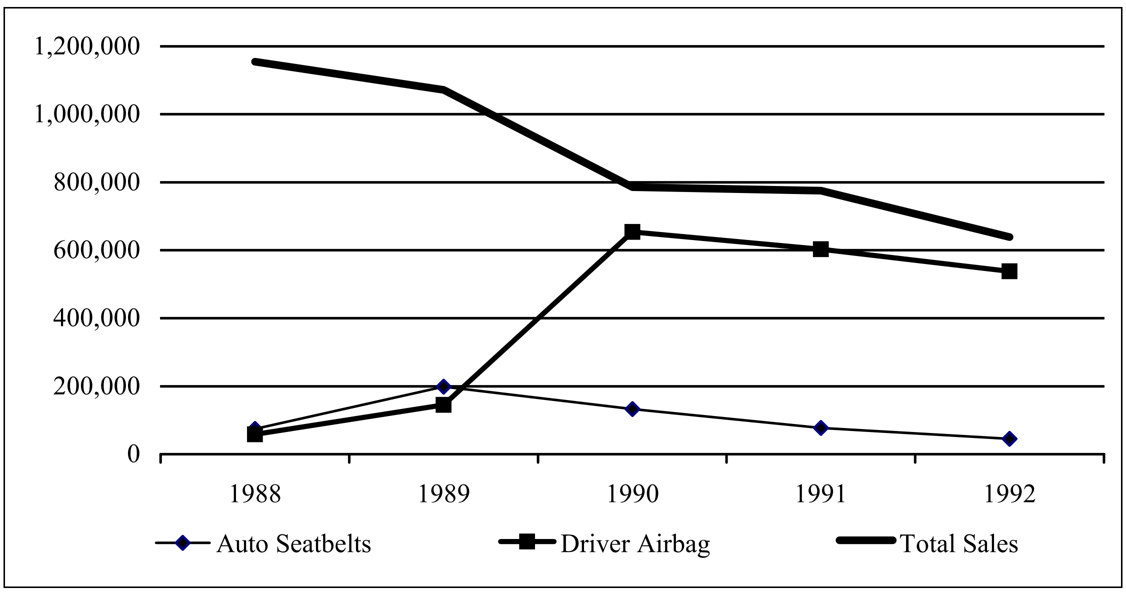
Passive Restraint Installation Trends and Total Passenger Car Sales (Asia)



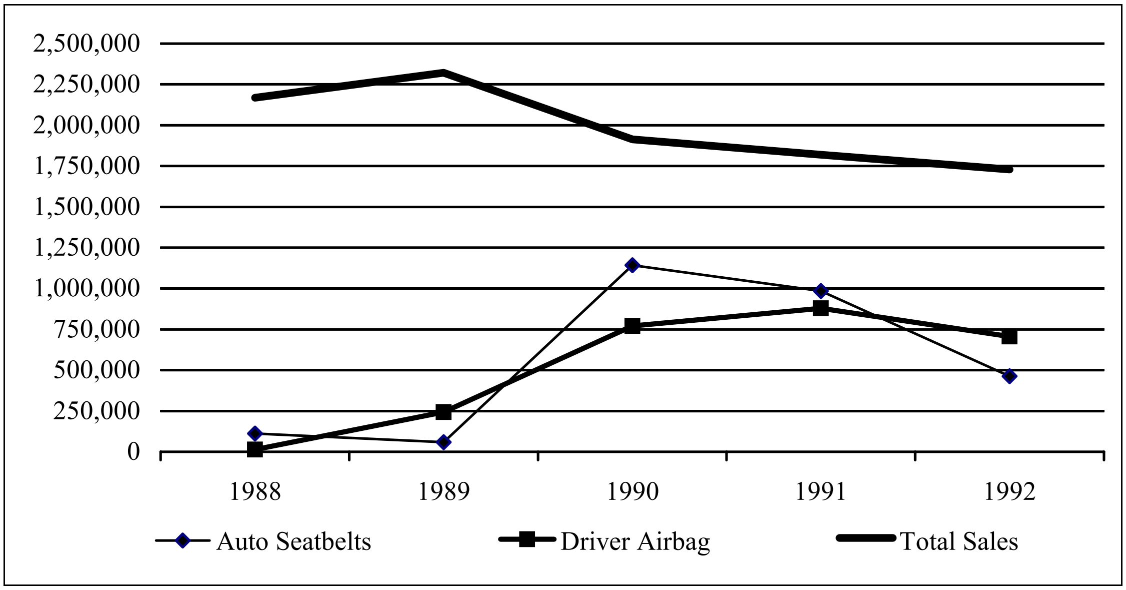
Passive Restraint Installation Trends and Total Passenger Car Sales (Europe)



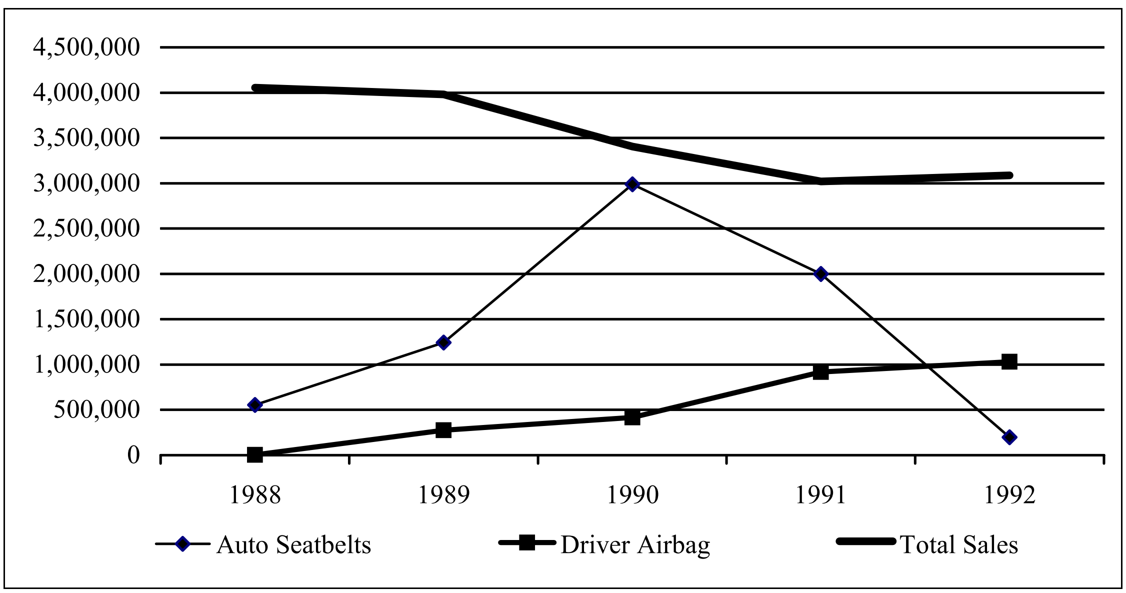
Passive Restraint Installation Trends and Total Passenger Car Sales (Chrysler)



Passive Restraint Installation Trends and Total Passenger Car Sales (Ford)



Passive Restraint Installation Trends and Total Passenger Car Sales (GM)



APPENDIX C: DESCRIPTIVE STATISTICS FOR PRICE ANALYSIS

All Vehicles

Category	n	mean	Minimum	Maximum	Standard Deviation
Small Car	152	268	-4051	3394	774
Midsize Car	75	449	-3062	5024	1148
Large Car	58	572	-2601	4043	1050
Luxury Car	154	685	-5449	7682	1863
Sports Car	56	674	-3240	5060	1251
Minivan	12	1448	-311	3384	1144
SUV	47	1433	-1879	6590	1830
< 15k	165	386	-1747	5060	785
15k – 25k	205	581	-4051	6590	1281
> 25k	184	830	-5449	7682	1877
Average All Vehicles	554	606	-5449	7682	1409

Driver-Side Airbag is made Standard

Category	n	mean	Minimum	Maximum	Standard Deviation
Small Car	23	370	-774	3394	830
Midsize Car	12	1175	379	5024	1279
Large Car	7	1487	0	4043	1245
Luxury Car	16	955	-3027	5107	1796
Sports Car	8	551	-1858	3361	1556
Minivan	2	1866	1831	1900	48.8
SUV	6	1208	560	2074	687
< 15k	24	393	-774	3394	819
15k – 25k	30	1055	-1858	5024	1248
> 25k	20	1129	-3027	5107	1699
Average All Vehicles	74	861	-3027	5107	1299

Passenger-Side Airbag is made standard

Category	n	mean	Minimum	Maximum	Standard Deviation
Small Car	14	-296	-3360	1248	1136
Midsize Car	6	1185	287	4090	1463
Large Car	6	1035	-730	2431	553
Luxury Car	30	1170	-2762	4658	1636
Sports Car	7	1023	-3240	3019	2067
Minivan	2	1658	1584	1732	105
SUV	7	1827	325	5978	2008
< 15k	12	-311	-3240	1248	1187
15k – 25k	23	799	-3360	4090	1411
> 25k	37	1351	-2762	5978	1719
Average All Vehicles	72	898	-3360	5978	1640

ABS is made standard

Category	n	mean	Minimum	Maximum	Standard Deviation
Small Car	18	1502	-55	3162	1142
Midsize Car	13	464	-1864	1509	822
Large Car	11	1445	67	4043	1086
Luxury Car	24	1159	-1207	5979	1582
Sports Car	8	927	-376	2612	1054
Minivan	11	912	-2058	3422	1514
SUV	18	1351	-49	5222	1428
< 15k	35	770	-1410	3144	993
15k – 25k	70	1148	-1864	5222	1145
> 25k	26	1135	-2058	5979	1728
Average All Vehicles	131	1045	-2058	5979	1247

APPENDIX D: BUREAU OF LABOR STATISTICS NEW CAR QUALITY IMPROVEMENTS 1968 – 2002

Year	*Average Retail Equivalent Price of All Motor Vehicle Quality Changes for New Cars*		*Average Change in MSRP for New Cars from Previous Year from BLS*		*Average Change in Transaction Price for New Cars*
	(Current $)	(2000 $)	(Current $)	(2000 $)	(2000$)
1969	$1.00	$4.69	$40.00	$187.68	NA
1970	$46.00	$204.15	$107.00	$474.88	NA
1971	-$6.00	-$25.51	-$15.17	-$64.50	$190
1972	$20.00	$82.39	-$1.00	-$4.12	$70
1973	$123.80	$480.14	NA	NA	-$265
1974	$117.90	$411.81	NA	NA	-$207
1975	$129.90	$415.78	$386.00	$1,235.49	$336
1976	$15.60	$47.21	$198.00	$599.22	$553
1977	$59.15	$168.08	$382.30	$1,086.34	$124
1978	$50.12	$132.37	$424.49	$1,121.12	$327
1979	$46.35	$109.94	$300.30	$712.28	-$607
1980	$241.51	$504.71	$365.85	$764.56	-$412
1981	$530.85	$1,005.64	$536.14	$1,015.66	$1,051
1982	$126.32	$225.41	$562.64	$1,004.01	$769
1983	$128.04	$221.37	$263.92	$456.30	$689
1984	$110.08	$182.44	$221.70	$367.44	$516
1985	$151.45	$242.38	$268.20	$429.22	$92
1986	$186.50	$293.02	$745.52	$1,171.34	$933
1987	$47.13	$71.44	$776.38	$1,176.87	$413
1988	$245.56	$357.44	$458.66	$667.64	-$11
1989	$182.89	$253.98	$559.35	$776.77	-$323
1990	$216.40	$285.11	$804.91	$1,060.49	-$139
1991	$215.06	$271.90	$672.77	$850.59	-$253
1992	$259.79	$318.86	$917.30	$1,125.87	$485
1993	$89.10	$106.18	$616.54	$734.73	$55
1994	$363.63	$422.52	$612.74	$711.97	$697
1995	$173.35	$195.87	$543.21	$613.78	-$510
1996	$193.03	$211.85	$494.98	$543.25	$316
1997	$185.53	$199.05	$333.34	$357.64	$347
1998	$230.81	$243.84	$363.27	$383.77	$558
1999	$15.50	$16.02	$125.27	$129.48	-$161
2000	$169.05	$169.05	$408.42	$408.42	-$997
2001	$212.67	$206.79	$422.51	$410.82	$652
2002	$63.80	$65.38	$377.94	$361.76	NA

APPENDIX E: DESCRIPTION OF AIRBAG RELATED PATENT SUBCLASSES

728.1 Inflatable passenger restraint or confinement (e.g., air bag) or attachment:
This subclass is indented under subclass 727. Devices wherein the attachment comprises a bag designed to inflate upon impact of the vehicle with an external object and thereby confine a vehicle occupant in a protective environment made up of a confinement bag and a vehicle seat.

(1) Note. A passenger-restraining device of the inflatable type is provided for only in this class (280).

728.2With specific mounting feature:
This subclass is indented under subclass 728.1. Devices combined with means to connect: (a) the bag housing to a vehicle, (b) the bag to a housing or an inflator or (c) an inflator to a housing.

728.3Deployment door:
This subclass is indented under subclass 728.1. Devices having a cover or lid which opens upon inflation of the bag.

729 Plural compartment confinement (e.g., "bag within a bag")
Devices under subclasses 728.1+ wherein the confinement (air bag) is made of a plurality of individual compartments or is made of two or more bags, one within the other.

730.1Inflated confinement specially positioned relative to occupant or conforming to the body shape of occupant:
This subclass is indented under subclass 728.1. Devices wherein the confinement, when inflated, is (a) positioned in a particular manner with respect to the occupant"s body or (b) is shaped or contoured with respect to a particular part of the occupant"s body.

730.2Mounted in vehicle and positioned laterally of occupant:
This subclass is indented under subclass 730.1. Devices wherein the confinement is stored during its nonuse or uninflated condition within the vehicle at the side of the occupant.

731 Deflated confinement located within or on steering column
Devices under subclasses 728.1+ wherein the confinement is stored in its nonuse or deflated condition within or on the vehicle steering column.

732 Deflated confinement located in or on instrument panel
Devices under subclasses 728.1+ wherein the confinement is stored in its nonuse or deflated condition within or on the vehicle instrument panel or "dash-board".

733 In the form of or used in conjunction with a belt or strap
Devices under subclasses 728.1+ wherein the inflatable confinement is 1) shaped as or resembles a belt, strap or harness arrangement and/or 2) is combined with a belt, strap or harness arrangement.

734 Responsive to vehicle condition
Devices under subclasses 728.1+ which are inflated in response to one or more particular vehicle conditions which assume impending collision or crash.

735 Electric control and/or sensor means
This subclass is indented under subclass 734. Devices wherein the confinement inflation initiation means and or condition sensor is electrical.

736 With source of inflation fluid and flow control means thereof
Devices under subclasses 728.1+ having an inflation fluid source or generator and the means to control such fluid flow from the source to the confinement or to the atmosphere or such fluid flow from the confinement to the atmosphere.

737 With means to rupture or open fluid source
This subclass is indented under subclass 736. Devices provided with means to open or rupture a closure in the fluid source to allow the inflation fluid to flow to the confinement.

738 With means to aspirate ambient air
This subclass is indented under subclass 736. Devices having means to draw ambient air into the flow line and mix such air with the inflation fluid, such mixture being the total or resultant inflation fluid which fills the confinement.

739 With confinement deflation means
This subclass is indented under subclass 736. Devices provided with means to deflate the confinement after inflation thereof.

740 With means to diffuse inflation fluid
This subclass is indented under subclass 736. Devices wherein the confinement is provided with means to diffuse or deflect the stream of inflation fluid, thereby spreading the stream of inflation fluid from a single point to a more general area within the confinement.

741 Inflation fluid source
Devices under subclasses 728.1+ having a specific inflation fluid source or generator therefore.

742 Flow control means
Devices under subclasses 728.1+ having a specific inflation fluid control therefore.

743.1 Specific confinement structure:
This subclass is indented under subclass 728.1. Devices wherein the confinement or the bag is provided with a specific shape or is defined by its specific structure.

743.2 With confinement expansion regulating tether or strap:
This subclass is indented under subclass 743.1. Devices combined with a strip or band which controls the inflation of the bag to conform to a certain shape or limit the extension of the bag.

Appendix F: Cost Figuring Methodology for NHTSA-Sponsored Studies and Reported Airbag Costs

The three reports responsible for the data provided in Table 3-3 are representative cost analysis studies as contracted by NHTSA. The estimates presented in these studies have been generated according to the methodology used by NHTSA since the first such report was produced in 1975. In developing cost estimates for proposed and existing safety standards, the objective of these studies is to derive three numbers: the direct cost to the manufacturer, the wholesale markup to dealer cost, and the dealer markup to the equivalent retail price to the car buyer. These studies are invaluable because detailed cost information of this type for airbags tends to be proprietary and exceedingly difficult to acquire. The uniformity in assumptions and methodology also make possible a direct comparison of the cost estimates, and keeps the internal validity of the reports intact.

Auto Industry Cost Factors:

1. *Material Costs:* Determined from the contemporary market price for a material.
2. *Variable Burden Rates:* Vary w/ the volume of production. For example: Setting-up the machinery, the handling of material, the cost of shipping.
3. *Corporate Overhead Expenses:* Do not vary with the volume of production. For example: 1. Depreciation 2. Amortization 3. Plant maintenance 4. Taxes other than income tax.
4. *Consumer Cost:* Obtained by using the estimated direct cost, adding the variable burden, factoring in the overhead, and determining the mark-up from dealer to customer. (Incentives are ignored in this study).
5. *Variable Cost x 1*.33 = Wholesale (Dealer) Cost
6. *MSRP = Variable cost x 1*.51

The cost-pricing formula used in NHTSA regulatory cost estimation:

- Allows all estimating to be done on a consistent basis
- Using variable cost as the starting point and predetermined mark-up rates
- Is based on real world, cost behavior patterns
- Is relatively simple to use

Markup Factors

- Manufacturer to wholesale 1.33
- Wholesaler to dealer (domestic and imported) 1.14

Variable cost development:

- For Operations:

  - Direct Labor Cost = DL*60/(pieces)*(# men) where DL = direct labor rate for one year

- Variable Burden Cost = VB/(places)*(# mach) where VB = variable burden rate for one year
- Manufacturing Burden Cost = MFG/(pieces)*(# men) where MFG = manufacturing burden rate for one year

▪ For materials:

- Direct Material Cost = ((rough wt * DM) + other * (year discount))*(1+scrap %) where DM = material cost for one year

▪ For total costs:

- In-house Variable Cost = (DM+DL+VB) * (# required)
- Out of house Variable Cost = ((DM+DL+MFG)*(# required)

▪ For Dealer, Other and Consumer Costs:

- VMFG = (DM+DL+VB)*(scale factor)
- Other Profit = ((VMFG) * (vc / wc factor)) – VMFG
- Dealer Markup = (dealer discount %) * (VMFG + other) / (1- dealer discount %)
- Consumer Cost = VMFG + other + dealer markup

The objective of the three studies was to "determine the cost of occupant restraint systems at annual volumes, manufactured and marketed according to typical North American automotive practices." The following assumptions were made to accomplish this objective.

1. The passive restraint systems analyzed in the study are obtained complete and ready to install, from a supplier located in the U.S. The components that are not produced in-house by the OEMs are received through a captive supplier of the automobile manufacturer.
2. In-house items include knee bolsters and all brackets, reinforcements, tapping plates, etc… Structural modifications to the car body in order to accommodate the added hardware are also made in-house. The costs of such modifications were determined by comparing the cost of each piece with the cost of that piece if it were configured for the baseline system.
3. Annual production volumes are assumed to between 250,000 and 350,000 units hence manufacturing processes appropriate to these high volumes were incorporated into the analysis. Volumes for subcomponents, which may be much higher, are estimated based on consultation with experts in the representative supplier industries.
4. In the case of dual airbags, tooling costs are assigned entirely to the driver airbag cost. Components for driver and passenger airbags are assumed to be the same except where noted.
5. Final costs include installation of the airbag systems in the vehicles.

6. For the first two studies it was assumed that when the entire new passenger-car fleet becomes equipped with airbags, the costs will likely be lower.

Review of Airbag Cost Estimates (1969-1992)

What follows is a brief historical review of airbag cost estimates reported in media and government sources during and after the period of time that airbags were considered as a possible alternative to meeting the passive restraint requirement.

1969
Ford engineers stated the company would introduce an airbag on the front-seat passenger side of the 1971 Mercury Marquis, a $4,500 car. According to the engineers, the device would add about $100 to the cost of car, and would be extended to other models if successful.[3]

1970
It was reported that Ford President Iacocca believes airbag safety devices could cost $200 per car.[4] In a memorandum to Peter Flanigan, White House Aide George Crawford writes, "with regard to passive restraints, DOT says airbags for 1973 would cost $100 [per car], for 1975 $150-$200."[5]

1973
Ford Motor Co. and General Motors both offered cost estimates during Senate hearings on "Air Bag Development and Technology." General Motors stated that the retail price of the airbag option the company planned to offer on its 1974 models was in the area of $200 with an additional $25 for front lap belts. GM also told the Committee members that the cost of developing the airbag system was $35 million to date, with a substantial amount of work left to do.[6] GM continued by stating that to make airbags standard on all of its cars would require "expenditures for facilities and tools in the area of $200 million." Meanwhile, Ford declared that a front seat airbag system would have a suggested retail price without a markup for company profit of about $215.[7]

1975
It was reported in the press that the Council on Wage & Price Stability may recommend against the installation of airbags on MY 1977 cars due to the $200 extra cost.[8] NHTSA head James Gregory was quoted as saying airbags would raise prices only about $106 per car.[9] Ford Motor Co. official William F. Browne, in response, warned that costs would be closer to $300 per car. Joan Claybrook, in the same article, said the $300 figure quoted by Ford was a result of "mere analysis," and advised NHTSA to use its power to subpoena cost and production data from automakers when they oppose safety measures on economic grounds.

1976
The new NHTSA head, William Coleman, predicted a car with passive restraints would cost $80 more than one with seat and shoulder belts, well below industry estimates of

$187 to $235.[10] It was unclear what quantities of airbags and automatic seatbelts Coleman was assuming in his optimistic cost estimate.

1977

At the beginning of 1977, DOT estimated that if all cars sold in the U.S. were equipped with airbags, the price per system would be $100. From this estimate, DOT determined that the price for the dual airbag GM system would be $100 and the Ford driver-side airbag, $50, unless the General Accounting Office or an independent accounting firm selected by DOT could determine that the cost should be greater.[11] Former GM President Edward Cole refuted the DOT's cost estimate in an interview in early March of that year. He stated that any estimate under $150 was unrealistic.[12] This was an important statement for the following reasons: 1) As former GM chief he helped pioneer airbag development and was as close as anybody to the technology and its cost implications; 2) He was a staunch proponent of airbags and wanted them in every car; and 3) He was retired and no longer formerly affiliated with the auto industry, which implied a greater candor in his statements than when he had been employed by the company. Secretary of Transportation Brock Adams dodged the issue somewhat when he stated that airbags would cost $100-$300. He said during the announcement on June 30th that all new automobiles sold in the U.S. by the 1984 model year must be equipped with either airbags or passive seat belts.[13] In August, Allstate Insurance Co. ran an ad to in part to rebut a *Wall Street Journal* editorial where airbags were negatively portrayed. The ad argued that airbags would increase the auto price by no more than $111.[14] An October 13 article in *The Washington Post* cited an airbag cost of $200 and a replacement cost of $600.[15] General Motors insisted that it could not produce airbags for "much less than" the $315 the company had charged between 1973 and 1975 for the systems when they were offered as options on some Buicks, Cadillacs, and Oldsmobiles. The demonstration plan set forth by the DOT in somewhat limited cooperation with automakers demanded the cost be under $100.[16]

1978

The Wall Street Journal wrote in June that the DOT had declared that Government requirements to increase the safety, fuel economy and damage resistance of automobiles would add about $285 to the price of a passenger car by 1984.[17] According to the DOT, the $285 figure represented the approximate expense automakers would incur by installing airbags or passive seat belts to new cars, following Federal rules for improved fuel economy, and adhering to Government standards for bumpers that would be less susceptible to damage in low-speed crashes. Interestingly, automaker estimates for airbags alone were often greater than $285 at the time.

1979

A 1979 report conducted by the General Accounting Office (GAO) attempted to provide an objective analysis of, among other things, the cost of airbags in varying production volumes. GAO considered separate cost estimates by Ford Motor Co., General Motors, and the National Highway Traffic Safety Administration (NHTSA). GAO reported that the incremental cost to the consumer for comparable airbag systems was $235 according to Ford, $193 for GM, and $112 for NHTSA.[18] The significant difference in cost estimates was due to the following methodological considerations, according to GAO:

1. Ford and GM included more sophisticated sensor and diagnostic systems than NHTSA, which analyzed an airbag system that would meet the minimum performance requirements of the agency's proposed standard.
2. A much higher dealer mark-up was used by industry to determine the final price to the consumer.
3. Ford included an overhead component to its cost estimate to account for indirect labor cost, taxes, insurance, general engineering support, purchasing, inventory control, etc…
4. GM included a commercial expenses component that estimated costs incurred from distribution, warehousing, product liability, service training, normal engineering, etc…

The study warns that, "too many uncertainties surround the introduction of air bag systems by 1981 to allow a high degree of confidence in these estimates." The above projections were also based on high volume production where the majority of an automaker's cars would be equipped with an airbag. The strategy of automakers to meet the pending regulation was to go primarily with the other, less expensive passive restraint option, the automatic safety belt. At production volumes that the industry considered to be more realistic, GM estimated a cost per system in 1979$ of $581 for the 1982 model year based on 400,000 units, and $509 for 1983 based on 750,000 units. Similarly, in July 1979, Ford estimated a cost per system in 1982$ of $828 at a production volume of 200,000 and $575 at 787,000 units. These numbers were not substantiated by a third-party source.

In a confidential memo, the Chrysler chief engineer provided estimates to A.C. Malliaris of NHTSA, that an airbag module would cost $491 at a volume of 6,000 units and $240 at 190,000 units (using an "estimated piece cost penalty based on vendor air bag module quotes.").[19] These cost estimates did not include amortization of tooling, pre-production and launch costs, engineering, research, and development, assembly cost, shipping cost, provision for liability, provision for warranty, and other contingencies.

1981

Ralph Rockow, chairman of the Automotive Occupant Protection Association, a trade group of airbag manufacturers, stated in front of a House subcommittee on consumer protection that he expected airbags produced in high volume to cost consumers a maximum of $250 to $300.[20] This was partly in response to the airbag cost alleged by GM of $1100 due to the relatively small demand that exists for the safety device. The press during the time stated that auto industry officials expected the airbag to add $500 to $800 to the price of such a vehicle.[21] Other press reports stated that airbags would cost between $100 and $200, but presumably this was not the cost to the consumer.[22] This wild variation in cost reporting reveals a major recurring problem with how airbag costs were reported. A dollar figure was usually thrown out without explanation to whether the cost represented the manufactured unit, an installed unit, or a complete airbag system as it is priced to the consumer. Production volumes, which heavily impact any cost estimate, are often not included either.

Clarence Ditlow, the head of the Center for Auto Safety, released the contents of an internal NHTSA memo that the Center had acquired, despite the contention by NHTSA that the documents contained “proprietary financial information” protected by the Trade Secrets Act. The document, dated July 11, 1979, contained an attachment that showed Ford Motor Co. estimated in 1978 that if it equipped 885,000 of its 1982 models with airbags, the cost to the company would be $101 per vehicle.[23] Another attachment listed the GM cost estimate of $96 if airbags were installed on 3.5 million of the company’s 1980 model cars. The cost to the consumer was estimated to be $206. The data in these attachments are reproduced in Table 3-2. A.C. Malliaris, the Director of the Office of Vehicle Safety Standards at NHTSA and the writer of the memo, recommended that the attached cost information and related materials should be declassified and made fit for public consumption. Furthermore, Malliaris avowed that “serious thought” should be given to designing a NHTSA Order requesting the manufacturers to produce all relevant material outlining their cost estimates and their decisions based on those assessments.

Professor William Nordhaus testified to Congress that a rescission of the passive restraint standard would have enormous societal costs attached to it. The costs of a rescission were estimated to have 3½ times the benefits. Nordhaus assumed high production and used an estimate of $400 for the cost of an airbag with an additional $25 lifetime fuel penalty.[24]

1982
The General Services Administration, through subsidies from NHTSA, contracted with Ford to purchase roughly 5,000 airbag-equipped cars for the federal fleet. It was reported that the cost would be between $300 and $500, but the cost could possibly be lower if the volume were large enough.[25]

1983
Raymond Peck, head of NHTSA, said the cost of putting airbags into federal cars in an attempt to stimulate a market for the safety devices could run as high as $500 per vehicle.[26]

1989
While airbag sales were starting to increase, the cost of a fully installed driver-side airbag was still reported to be greater than $500.[27] The cost was predicted to be falling due to the nature of governmental regulation leading to technological advances and per unit cost-drops due to mass production. Analyst Thomas O’Grady of Integrated Automotive Resources estimated that airbags would raise the price of cars between $300 and $400.[28] Robert Stempel, President of GM, warned that each airbag the company installed would cost over $500. Meanwhile, Ford spokesman Bill Carroll estimated that a driver airbag would add between $350 and $700 to the final price of each new 1990 model.[29]

1990

In Japan, Nissan announced its plan to offer at least optional airbags on all of its models by the 1992 model year. The airbags were expected to cost from 100,000 Yen (~$630) to 150,000 Yen (~$950).[30]

1991

The cost of airbags was reported to have fallen dramatically during the previous two years. According to the primary automotive trade magazine *Automotive News*, an airbag system had until recently cost between $500 and $1000, but that now a basic driver-side airbag including manual lap belts costs up to $175 depending on the vehicle model and manufacturer.[31] An additional passenger-side airbag was reported to add about $270 more. The more complex airbag systems used primarily by European automakers cost up to $600 for the driver-side and an additional $250 for the passenger-side. The article cited safety engineers who maintained that prices were falling rapidly as suppliers streamlined production methods, technology improved, and volume increased. The cost of a driver airbag from the supplier to the automaker was estimated to be between $175 and $200, but factoring in the additional costs of R & D, engineering, tooling, facilities, assembly labor, liability reserves, taxes and overhead, the true cost to the manufacturer is closer to $450 to $500.[32] The reports from Canada also confirmed this rapid decline in airbag costs. It was reported that the price of airbags had come down in only two years from between $900 and $1,200 Canadian per unit to between $300 and $350.[33]

1992-present

The *Financial Times* (of London) reported that competition played a central role in reducing airbag costs.[34] It indicated that the cost of an installed air bag fell from more than $ 1,200 to approximately $ 100 in less than five years because of aggressive cost reductions by air bag suppliers and new assembly methods introduced by car manufacturers.

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FINAL REPORT

Contract 02-310
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Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking –

A Review of Consumer/Citizen Response to Climate Change and Strategies to Reduce Greenhouse Gases in the Light-duty Automotive Sector

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Disclaimer

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

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Abstract

We review research on consumer vehicle purchase and use behavior and citizen support relevant to potential greenhouse gas emission policies that might require alternative technologies or increase the cost of fuel or vehicles. We focus on fuel efficiency as a CO2 reduction strategy, recognizing there is a variety of other ways greenhouse gas emissions might be reduced in the transportation sector. Research on consumers and energy use comes from federal regulators looking for ways to reduce fuel use, automakers and automotive marketing research companies wanting to know what motivates buyers, and a few academic, NGO, and foundation-sponsored researchers. Additionally, there has been some research in recent years related to green and social marketing of vehicles. Finally, we are in the midst of completing detailed household interviews on consumers and fuel economy; we discuss preliminary results from that work in this review.

It is of great interest to predict how much consumers will pay for technological advances that enhance fuel efficiency. Based on issues discussed in the review and results of our recent interviews with car and truck buyers, we believe measuring willingness to pay for fuel economy technology is a problematic research direction. If buyers think more efficient vehicles are a good idea, they may want them regardless of such calculations. In this sense, marketing will have more impact on responses to questions about willingness to pay than calculated fuel cost savings.

Executive Summary

Through Assembly Bill 1493 the State of California seeks to lower emissions of carbon dioxide (CO_2) by motor vehicles so as to limit climate change caused by the buildup of greenhouse gases in the atmosphere and thus ameliorate the negative impacts of such climate change on air quality in California. Reduction of CO_2 emissions from motor vehicle travel in California is not a simple proposition technically or socially. In light of the growing economy and population of California, achieving these reductions over the next few decades will require a comprehensive strategy that integrates and balances technical advances, regulatory action, and market forces. To make progress in any such strategy, Californians will be called on to act as both consumers to buy new products and citizens to support policy. In this report, we review research on past, current and future consumer behavior around vehicle purchases and citizen support that is relevant to potential policy avenues that might require alternative technologies or increase the cost of fuel or vehicles. We focus primarily on fuel efficiency as a CO_2 reduction strategy, recognizing there are a variety of other ways greenhouse gas emissions might be reduced in the transportation sector.

The terms “fuel economy” and “fuel efficiency” have important historical, legal, and technical distinctions and so we spend some effort in this report to explain how those terms are used in past research and in this report. The basic distinction we highlight is that the phrases “fuel efficiency” and “fuel economy” have specific meanings and therefore a specific relationship to each other in the minds of energy experts; the vehicle buying public does not in general share these definitions and distinctions. To (some) experts, efficiency is a narrow measure of the ratio of useful energy out of an engines crankshaft to the energy input; “fuel economy” is codified to mean miles per gallon. From this perspective, increased fuel economy is just one service that can flow from increased efficiency.

In this study, we focus upon—from narrow to broad—consumer response to reduced grams of CO_2 per mile, and therefore consumer response to improving the fuel efficiency of internal combustion engines and auxiliary systems, and thus reduced CO_2 produced in the course of the use of light-duty vehicles. Research on consumers and energy use comes from primarily three sources: federal regulators looking for ways to reduce fuel use, automakers and automotive marketing research companies wanting to know what motivates buyers, and a few academic, NGO, and foundation-sponsored researchers also interested in reducing fuel use. Additionally, there has been some research in recent decades related to green and social marketing of vehicles.

Very little past research is directly useful for our purposes; we must tease out bits and pieces of data and insight. We must often discuss past research that has focused narrowly on the issue of fuel cost savings and vehicle mile-per-gallon ratings, but not fuel efficiency, fuel economy, or greenhouse gas emissions. In some cases we must tease out insights from highly aggregated economic studies, which assume an overly rational model of car buyers. Also, questions have been asked in a way which makes sense to researchers for their purposes, such as probing consumers about “willingness to pay” or “payback periods” but not in a way which is relevant to car buyers decision processes or the structure of the market.

Past research at the Institute of Transportation Studies at UC Davis has focused on consumer response to alternative fueled vehicles, touching at times on the issue of consumers and fuel economy. But we are in the midst of completing more detailed work household interview work on consumers and fuel economy for the Energy Foundation and U.S. Department of Energy; we discuss preliminary results from that work in this review.

In general, this review covers the history of consumer response to fuel costs, fuel use, and the technical variables affecting fuel use and cost. Perhaps surprisingly, the real per mile cost of gasoline to drivers has remained stable over the past 100 years, while vehicles have become faster, bigger, and have added more fuel consumptive technologies over time such as automatic transmissions and four-wheel drive. Most importantly, consumers buy more cars and trucks per household, and drive many more miles than in the past. Amidst these changes, gasoline is a less significant portion of household budgets and has dropped below automotive insurance and financing as an expense in most households. Over the time period of 1967 to 1992, consumers demonstrated they would pay considerably more for vehicles, both for “regulated” safety and emissions improvements, as well as for luxury, quality, reliability, performance, and size. The missing data for this analysis are comparable data for light-duty trucks. A complete accounting of the effects of safety and emissions regulations on car sales would have to address the degree to which the shift of the new vehicle market towards trucks was driven by more lenient safety, emissions, and efficiency regulatory treatment that allowed lower manufacturer costs.

Most, economic studies of consumer response to high gasoline prices date to the oil crisis of the 1970s and early 80s, and show that car owners in that period did not reduce their travel much in response to gasoline price rises (as opposed to actually gasoline supply disruptions and rationing), and that during that transition period, those buying new cars were able to reduce their fuel use, while used car buyers and non-buyers retained vehicles with worse fuel economy. These studies do not tell us however how consumers might respond to offerings in the market of advanced technologies with better fuel efficiency.

Research in household and automotive energy use shows that consumers do not have good information about their energy expenses, do not keep records of annual expenses, and do not have good energy instrumentation on most appliances and vehicles to keep them informed of energy or fuel use. There is a wide distribution of consumer fuel cost accounting behaviors, from those who are highly informed to those who keep no records and do no calculations of fuel economy; consumer consideration of fuel economy varies. When we ask car owners about fuel use and costs, most householders “confess” they probably should know, but that they have no idea. Perhaps the piece of knowledge about automotive fuel costs known by most drivers is the price of a gallon of gasoline or the cost to them of a recent tank of gasoline.

It has become common practice in the automobile marketing research industry to ask consumers to “rank” the relative importance of lists of aspects, features, or attributes of vehicles in their choices. Fuel economy ranked high in these studies in the early 1980s, but dropped very low in the 1990s, recovering a bit recently in the wake of higher fuel costs. Many studies of fuel economy choices have centered upon the tradeoffs between weight, power, size, and other energy consuming attributes of vehicles. And in fact, consumer demand for larger, more powerful vehicles has been a major feature of the market, along with demand for four-wheel drive, air conditioning, and other energy using devices. We review data from auto companies and other sources that show consumers want these things over fuel economy. On the other hand, advanced technologies, such as hybrid drive trains will offer fewer compromises than in the past and perhaps other amenities such as greater auxiliary energy, so research that characterizes fuel economy as a tradeoff is not an altogether accurate portrayal of the market situation.

It is of great interest to regulators and car makers to predict how much consumers will pay for technological advances that enhance fuel economy and efficiency, but buyers are not accustomed to paying more for better fuel economy, that is, for vehicles with lower fuel costs per mile. Consumers might respond to close-ended prompts (such as “would you pay $500, $1000, or $1500 for better fuel efficiency?”) or even offer some dollar amount off the top of their head. But we are finding in our own work that lots of consumers are guessing, uninformed, overly optimistic, or in some cases answer with what they think such improvements *should* cost—not what they personally would be willing to pay. Based on issues discussed in the review below and results of recent interviews with car and truck buyers, we believe measuring willingness to pay for fuel economy technology is a problematic research direction. If a buyer thinks the hybrid vehicle is a good idea, they may want it regardless of such calculations. In this sense, marketing will have more impact on responses to questions about willingness to pay than calculated cost savings on fuel.

Few analysts outside economic traditions accept the plausibility of consumer calculation of payback periods, and in economics it is more of a normative position—how consumers ought to behave. Ongoing research at ITS-Davis to understand household automotive purchases indicates that few buyers would engage in payback calculations; in fact we have found no household that thinks about fuel economy in terms of a payback period. When asked to do so, almost all participants are clearly unfamiliar and uneasy with the concept. A few grasp for familiar temporal anchors, e.g., their vehicle loan finance period, which are irrelevant to properly structured payback period calculations. Moreover, we have found that in many instances, consumers are overly optimistic about savings from better fuel economy. That consumers do not think of a pay-back period for fuel economy is not surprising when we compare fuel economy to most of the other things consumers want; ample speed, an attractive design, ample seating, and luxury options appear to have no economic payback aspect in consumer thinking about cars and trucks.

The history of light-duty diesel vehicle markets in the US in the 1980s and Europe in the 1990s offer some glimpses of consumer response to differences in vehicle and fuel costs, although not as clearly as we would hope. We also review studies of consumer choices for compressed natural gas in New Zealand in the 1980s as those also show the interaction of pump prices, fuel costs, and government incentives. Also, we discuss the emerging markets for hybrid vehicles in California and the US. Finally, we review recent work at ITS in which we study the issue of willingness to pay and payback explicitly with a variety of households in the region around Sacramento, CA.

This review points to two diverging viewpoints. On the one hand, if consumers were to think in terms of pay back periods (and the related metric, discount rates) then averages such as the “three year” figure that Greene (2002) provides by example are of little interest. Almost every study conducted of consumer payback periods related to energy conservation shows a wide variety of (generally implied) discount rates. This suggests the existence of a market that can be segmented according to how long people are willing to wait to be paid back. We should not be concerned initially with the “average” payback period, but with those people who are willing to wait longer. Still, even within a context where payback period calculations were imposed on consumers, those signals carried far more than price information. In the case of dual-fuel vehicles in New Zealand, payback periods—as an explicit element of government policy—came also to signify government commitment to alternative fuels. The payback calculation and government loans were part of an overall package of price supports and taxes, refueling station incentives, and other government support for alternative fuels. Across the board retrenchment on all these programs created uncertainty that may have had more to do with the continued decline and eventual end of New Zealand's experiment with natural gas as a transportation fuel than did the actual effect on vehicle conversion and fuel prices. This experience speaks to the need for a long-term transition strategy, not simply a short-term "launch" strategy.

If on the other hand as we will argue here, consumers simply do not evaluate vehicle price and fuel economy in a rational economic framework, then we must penetrate the veil of modeling behavior "as if" consumers were rational to understand the real effects of various policies. Our recent interview work suggests that "fuel efficiency" is a more compelling message than "fuel economy." It suggests that those who are buying hybrid vehicles are buying "whole bundles" of desired attributes; they are not buying what they consider to be economy cars.

As for consumer consideration of social and environmental value related to climate change, only in recent years have some consumers become aware of the role of transport fuel efficiency in global climate issues; the majority of consumers are relatively unaware or at least poorly informed of the role of fuel efficiency in the formation of greenhouse gases. Many of the initial buyers of hybrids and electrics are those who have made a decision to be pioneers of the new technologies for both cleaner air and to reduce their use of natural resources. It is still unknown how large this segment could become as knowledge of climate change improves and the role of fuel efficiency in climate change becomes more widely understood by the car-buying public. We supply an expanded discussion of polling data on Californian and American beliefs about policy on global warming in Appendix A.

1 Introduction: Reducing CO_2 from light-duty vehicles in light of present and future consumer behavior

Through Assembly Bill 1493 the State of California seeks to lower the emission of carbon dioxide (CO_2) by vehicles so as to limit climate change caused by buildup of greenhouse gases in the atmosphere and thus ameliorate the negative impacts of such climate change on air quality. Reducing CO_2 emissions from motor vehicle travel in California is not a simple proposition technically or socially. In light of the growing economy and population of California, achieving these reductions in the next few decades will require a comprehensive strategy that integrates and balances technical advances, regulatory action, and market forces. To make progress in any of these strategies, Californians will be called on to act as both consumers to buy new products and citizens to support policy. In this report, we review research on past, current and future consumer behavior around vehicle purchases and citizen support that is relevant to potential policy avenues that might require alternative technologies or increase the cost of fuel or vehicles.

Additionally, to develop effective policy and regulatory mechanisms, the State will need to understand current and potential consumer response to vehicles with reduced greenhouse emissions, including advanced fuel-efficient vehicles. Understanding consumer and citizen choices is not simple; consumers both complain about pump prices when gas prices go up yet appear to pay little attention to fuel costs in vehicle purchases or travel choices. Both automakers and energy researchers have patterned ways of thinking about consumer and fuel efficiency. Because fuel efficiency is so important to energy researchers, they tend to over-think consumer consideration of fuel-cost savings, when for their part consumers do not measure or calculate their fuel costs. On the other hand, because the market for high fuel economy vehicles has dropped in recent years with the low price of gasoline, and with the issue of greenhouse gases and green marketing so new to the automobile market, automakers have not been paying much attention to fuel efficiency in design, advertising or marketing until very recently with hybrid vehicles. In this report, we try to sort out research on past, current and future consumer behavior that is relevant to potential policy avenues, especially those that might require alternative technologies or increase the cost of fuel or vehicles.

CO_2 is a normal byproduct of internal combustion engines that burn carbon-based fuels such as diesel, gasoline, propane, ethanol, or natural gas. CO_2 from transportation is one of the main sources of anthropogenic greenhouse gases. Some strategies to limit CO_2 could include reducing the number of miles vehicles are driven in California through pricing, transit and other modes of travel, greatly improving the efficiency of internal combustion vehicles, shifting to bio-fuels that require returning carbon to living plant tissue for sustainable yields, or shifting to low and minimal carbon energy systems such as grid powered electric vehicles (recharged with non-carbon based energy sources such as wind or solar) and hydrogen fueled vehicles.

Reducing travel through pricing or transit has not kept down vehicle use in growing economies; even in Japan where transit is well developed and driving costs are exorbitant, personal vehicle travel is increasing. Alternative fuels and low carbon fuels are promising but more dependent on major changes in the refueling infrastructure. Relatively simple transitions to some alternative fuels, like methanol, have not been successful.

Of all the strategies listed above, the one that seems technologically closest at hand and most politically acceptable is to encourage advance technologies to improve the efficiency of vehicles powered by internal combustion engines. Still, these advance technologies are not easily implemented; advanced technologies usually cost more and may be unfamiliar to consumers. For example, hybrid electric drive trains are available only in a fraction of the 1000 or more make/models and makes of vehicles on the market. Not just new, but even some old technology, such as diesel engines, took several decades to gain a majority share in the European auto market, even with the encouragement of policy.

Nevertheless, we are in a period of the most radical transformation of vehicle technology since motor vehicles were invented, much of that change driven by environmental problems, advances in computer and other new technology, as well as increasingly and increasing global markets for automobiles and petroleum. Right now, the automobile industry and market is entering a period of rapid change in regards to these new technologies and new environmental goals, particularly in regards to global climate change concerns.

1.1 From fuel economy to fuel efficiency; a transformation of technology and values

The terms “fuel economy” and “fuel efficiency” have important historical and technical distinctions and so we spend some effort here to explain how those terms are used in this report. In this study, we focus upon—from narrow to broad—consumer response to reduced grams of CO_2 per mile, and therefore consumer response to improving the fuel efficiency of internal combustion engines and auxiliary systems, and thus reduced CO_2 produced in the course of the use of light-duty vehicles. However, the term *fuel economy* has a history in federal regulation related to fuel shortages in the 1970s, the potential security problems from declining oil reserves in the United States, and the subsequent regulation of fuel consumption through Corporate Average Fuel Economy standards, and the EPA fuel economy ratings. Additionally, consumer organizations and carmakers have also used these “economy” rating to identify and promote the vehicles with the higher fuel economy ratings. Additionally, some cars with the worst fuel economy ratings have been subject to gas-guzzler taxes. This historical use of the term “fuel economy,” while strictly defined as miles per gallon (see discussion in next sub-section), is about saving both fuel and money.

Energy and engineering experts, and automobile manufacturers in particular, stress the difference between fuel economy (MPG) and fuel efficiency. They wish to narrow the definition of fuel efficiency to its strictest technical measure—the ratio of useful energy out of an engine’s driveshaft to a unit of input energy (stored onboard the vehicle). With this definition of efficiency, things like increases in fuel economy, size, weight, luxury amenities, towing, four-wheel drive, and more are all services that can flow from increases in efficiency.

We may be moving from a past in which fuel economy was a primary component of a cost axis in the automobile market to a future in which fuel efficiency is a primary component of a value axis. Fuel economy is linked to a past in which many Americans had to budget their use of gasoline and fuel economy was associated primarily with reducing vehicle size, weight, and power; vehicle economy stood in contrast to luxury and power. To many consumers, fuel economy carries the notion of cheap vehicle. Along side this notion of economy, federal fuel economy provisions such as Corporate Average Fuel Economy standards were shaped by national security concerns stemming from the 1970s and 1980s oil costs. But with the low real price of gasoline in the past couple of decades compared to the escalating cost of other aspects of vehicle ownership—e.g., purchase price, financing, and insurance—fuel economy has been shrinking in importance in the vehicle market. Despite minor ups and downs in gasoline prices in the last few years, almost all growth in the automobile market has been towards larger, more powerful, and less economical vehicles. The economy segment of the market shrinks along with profits from that segment.

But as fuel economy has lost much of its market value, fuel efficiency, advanced technologies, and environmental values are an emerging value axis for consumers. Advanced technologies, such as hybrid vehicle systems, promise improved fuel economy without sacrificing luxury, size, weight, and power. And such new technologies offer cleaner air and reduced CO_2 emissions. We are studying consumers in a period of transition in technology, knowledge, and values. Given the history of fuel economy and its close relationship to fuel efficiency, we sometimes discuss research which is about consumer response to "fuel efficiency" of vehicles, and in some locations we discuss consumer response to cost savings from better "fuel economy" as those bear a indirect relation to consumer demand for vehicles that have reduced CO_2 emissions and better fuel efficiency.

1.1.1 Expert and legal uses of the terms fuel economy and fuel efficiency

The National Highway Traffic Safety Administration (NHTSA) officially defines fuel economy ratings as "the average mileage traveled by an automobile per gallon of gasoline (or equivalent amount of other fuel) consumed as measured, in accordance with the testing and evaluation protocol set forth by the EPA." The Energy Policy Conservation Act (1975) added Title V: Improving Automotive Efficiency to The Motor Vehicle Information and Cost Savings Act of 1973.

The Alliance of Automobile Manufacturers (AAM) takes a more consumer oriented bent on their website, defining fuel economy as the dollars spent on fuel per mile and efficiency as the power available at the driveshaft per unit energy input. The AAM gives credit to automobile manufacturers for increasing the technical fuel efficiency of vehicles, but they claim consumer choices for more energy consuming vehicles is responsible for the declines in fuel economy. Increased output energy can be used to propel the vehicle further (per unit of energy input), it can drive increased auxiliary loads, it can drive a larger vehicle, or it can be dissipated in automatic transmissions and four-wheel drive systems. Improvements in efficiency can be used to increase fuel economy, or to increase the weight, power, or payload of a vehicle while maintaining the same economy rating.

1.1.2 Consumer uses of the terms fuel economy and fuel efficiency

Most consumers we have interviewed say fuel economy and fuel efficiency mean the same thing to them. If pressed for a distinction, many will say fuel economy is about money, and fuel efficiency is about how much gasoline is used. One respondent stated that fuel efficiency is a "classier" way to say fuel economy. When we ask what car comes to mind when we say "a car with good fuel economy," many say "a small, economical vehicle; a Geo Metro." When we ask about "a fuel efficient vehicle," those respondents say " a Honda Civic, a Toyota Corolla" and note that these are higher quality vehicles than "economy cars." A few respondents associate fuel efficiency with the new Prius or Honda Civic Hybrid, and even bring up the idea of "saving natural resources." None mention greenhouse gas or CO_2 reductions, nor do they mention climate change in general. It seems clear to us from even a limited number of interviews that it is unlikely consumers in general make the distinction between fuel efficiency and fuel economy that experts do. The implications for this lack of shared understanding include the possibility of mistaken inferences and conclusions from surveys and other research on consumers.

2 Sources of research on consumers responses to improved fuel efficiency, global warming issues and other environmental factors in the vehicle market

Research on consumers and fuel efficiency comes from primarily three sources. These are federal regulators looking for ways to reduce fuel use, automakers and automotive marketing research companies wanting to know what motivates buyers, and a few academic, NGO, and foundation-sponsored researchers also interested in reducing fuel use, emissions of criteria pollutants or greenhouse gases. Additionally, there has been some research in recent decades related to green and social marketing of vehicles. Very little of this research is directly useful for our purposes; we must tease out bits and pieces of data. Most often, questions have been asked in a way which makes sense to researchers for their purposes, but not asked in a way which is relevant to car buyers decision process or the structure of the market.

2.1.1 Federal research on consumers and fuel efficiency

In the past, the federal government has conducted a limited amount of research on consumers and fuel efficiency. In recent years federal agencies have been limited in their ability to conduct research on US citizens. The primary cause is The Paperwork Reduction Act that requires federally supported research with more than nine respondents to gain Office of Management and Budget approval prior to being implemented. Thus federally funded research has been limited to buying a few questions in others' polls, and focus group studies. Focus groups have been conducted by Oak Ridge National Laboratories on the topic of fuel economy. Also, the National Renewal Energy Laboratories, working with the Office of Transportation Technologies at DOE, periodically hires a few questions on national surveys by Opinion Research Corporation International (ORCI). These studies have been aimed at a number of topics related to fuel efficiency, including understanding how consumers consider fuel economy in their current purchases, respond to major improvements in fuel economy, and might response to information about fuel economy, including websites and labels for new vehicles. We include a number of these federal studies in this review.[1]

2.1.2 Automaker research on consumers and fuel efficiency

Automakers have sizable consumer research programs, which feed advertising, branding, pricing, marketing, and product design strategies. However fuel economy has not been a high-

[1] We do not include a review of the CAFE review recently conducted by the National Academies of Science.

priority topic because consumers did not show much interest in fuel economy during the late 1980s and 90s when gasoline prices were low and declining in real terms. Moreover, most automotive market research is kept secret; when automakers find a research result that may provide a competitive edge, they keep it to themselves. What they do release is for strategic purposes, and in the case of fuel economy, the main purpose has been to avoid more stringent regulation. For example, the 13 member Alliance of Automobile Manufacturers (AAM) website devotes several pages to arguing that the growth of four-wheel drive, light-duty truck sales is driven by consumers' desires for safety, passenger room, cargo space, towing ability, and off-road capability. They quote Ward's Motor Vehicle Facts and Figures (2000, pg, 15) that the light-duty truck segment has grown from 22 percent in 1980 to 50 percent in 1999.

Similarly, in a 2001 presentation to the National Academy of Sciences, Mark Thibault, from General Motors (GM) represents well the view of the car manufacturers. He states that:

- Fuel economy is a secondary concern in all segments except low priced vehicles (13.9 percent of market) and the hybrid car segment (0.1 percent of market);
- Styling, price, quality, functionality, and safety are significantly more important in vehicle purchases;
- In general, the higher the price of the vehicle, the less important is fuel economy;
- Willingness to pay for fuel economy is low; and
- Consumers will not make tradeoffs for better fuel economy (MPG) unless fuel prices increase significantly or consumers fear a supply disruption.

He concludes that an automobile manufacturer could gain market share if they simultaneously meet all "primary" needs and were then still able to improve fuel economy.

Less oriented to arguments about CAFE standards are survey findings by major private research companies, such as J.D. Powers, Maritz, Dorhing, and AutoPacific. Most of these studies are for sale, but some findings are occasionally released for publicity purposes.

2.1.3 Economic studies of consumer demand for fuel economy and fuel efficiency

In reviewing the economic literature we see how the underlying reality of past vehicle options shapes expert analysis. That past reality is reflected by the most common description we have heard and read of vehicles that get good fuel economy, that such vehicles are small. This perceived diminutiveness often extends to performance, comfort, and safety. We hear this description in our household interviews and we read it in the expert literature. This perception leads to the expectation that vehicles with higher fuel economy ratings ought to cost less than vehicles with lower ratings. Until quite recently, with the advent of hybrid electric vehicles, consumers have not faced the prospect of paying more for a more fuel economical vehicle. Experts have not had data to analyze on such revealed choices, except in such cases as we discuss below in which changes in fuel economy are accompanied by changes of fuel or propulsion technology.

The effects on expert analyses include the following: choice of problems to analyze—and importantly, the very incidence of any studies at all; assumptions that shape what are—or are not—"surprising" findings; and inferences drawn from models. We have characterized economics as an attempt to operationalize a fairly specific set of assumptions about consumption (and production) decisions within mathematical models, and to conduct experiments within those models (Kurani and Turrentine, 2000, p. 13.) Compared to other social sciences, economists share a far more singular core set of assumptions about human behavior. The cornerstone of economic thought is that firms, individuals, and households act in their own interest and make rational decisions when making choices. Consumers are assumed to have stable, ranked preferences for goods, or features of goods, and good information about all their options. Choices are constrained by budgets and consumer research is often framed around prices—how much will people pay for what amount of which products (ibid).

So, related to vehicle and fuel purchase and use decisions, economists have studied, for examples, household response to higher gasoline prices (see for example Kayser, 2000; Pitts, Willenborg, and Sherrell, 1981; Puller, and Greening, 1999), aggregate economic impacts of inaccurate EPA mileage estimates including impacts on consumer surplus (see for example Sennauer, Kinsey, and Roe, 1984), and competing effects (primarily fuel cost savings versus safety) of CAFE standards (see for example Yun, 2002).[2] Notably, we find no studies that directly analyze whether households will pay more to buy vehicles that have higher fuel economy—except in the alternative fuel and electric vehicle literature where lower per mile operating cost was a promised attribute of some alternative fuel and electric vehicles.

Regarding the incidence of analysis, long periods of quiescence in gasoline prices such as most of the period from the mid-1980s to the late-1990s have not attracted the attention of analysts. Even some very recent studies are re-analyses of data from the period of most concentrated historical change in gasoline prices and vehicle fuel economy—the early 1970s to early 1980s. See Kayser (2000) as one example of a recent study conducted on older data. Data from the 1981 Panel Study of Income Dynamics because "data from 1981 are the most recent data for one year in which gasoline prices were changing rather substantially." While the data may allow for observation of consumer behavior under substantial changes in gasoline prices, it does invalidate some of Kayser's inferences if we are looking forward rather than backward. Specifically, Kayser concludes, "It appears that higher income allows households to purchase newer cars that will on average be more fuel-efficient because cars in 1981 are subject to the corporate fuel efficiency standards." Clearly the context has changed since 1981. New vehicles are not likely to be more fuel economical. CAFE standards have not been made more stringent, and new "cars" are now as likely to be less economical trucks. The question now is, will higher income households drive fleet average fuel economy up or down in an era when new vehicles may be either more economical, e.g., hybrids, or less economical, e.g., SUVs?

The impact on Pitts, Willenborg, and Sherrell's (1981) analysis of the practical means through which consumers could obtain a more fuel economical vehicle during the time period of their analysis (1973 to 1979) is revealed in their statement that, "The consumer may be required to make major changes in lifestyle by driving less or *by exchanging comfort, safety, or other satisfactions for smaller car fuel efficiency*." [Emphasis added.] They continue in this theme when explaining attitudinal variables they include in their analysis, "The comfortable-life variable was included in this study because, intuitively, many actions to downsize [household's]

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[2] Studies of the magnitude (and existence) of a "rebound effect" in which changes (increases) in fuel economy feedback through vehicle use behavior (to consume some of the expected fuel use reductions by increasing the number of miles driven) are the subject of another study for CARB and are not reviewed here.

automobile inventories would require purchasing smaller vehicles, and experiencing a corresponding increase in physical discomfort."

Much of the analytical literature on vehicle and fuel choice from the mid-1980s to the present focused on alternative fuels, electric vehicles, and air quality. Inferences for our question—will households pay more for higher fuel economy—are confounded by the fact that any fuel cost savings of alternative fuels or EVs is due at least in part to the use of a fuel less expensive than gasoline (where prices are measured "at the pump," not in a full fuel cycle analysis). Kurani and Sperling (1987) discuss how buyers of light-duty diesel vehicles in California during the late 1970s and early 1980s were seeking lower fuel costs through the higher efficiency and higher fuel economy of diesel engines *and* the lower pump price of diesel fuel. Owners of diesel vehicles felt disaffected when the pump price of diesel fuel surpassed that of gasoline. Natural gas and electric vehicles have been represented as cheaper to operate, due at least as much to lower unit fuel prices as any changes in efficiency or economy compared to gasoline vehicles.

The policy goals driving alternative fuel and electric vehicle research efforts affected whether and how the fuel economy of competing vehicle options were presented to respondents. For example, Golob et al (1995) presented fuel economy information about all the vehicle types, e.g., gasoline, methanol, natural gas, electric, within the context of refueling costs only, expressed as equivalent gasoline vehicle fuel economy. For example, the home refueling cost of a natural gas vehicle in one specific hypothetical choice example would have been represented as "4 cents per mile (25 MPG gasoline equivalent)." The general context then is one in which differences in fuel economy differences are presented, but they exist both within and across different fuel types, and are presented solely in terms of private costs per mile.

2.1.4 Green and social marketing research

For the most part, overall emissions of criteria pollutants and differences in such emissions from vehicles have been regulated during past decades. Notably, such differences have not been marketed, and therefore, automakers, federal and state governments have done little to educate vehicle buyers in a systematic or comprehensive way about differences in emissions between vehicles. This same relative lack of education and marketing is apparent with regard to the role of CO_2 in global warming and the role of fuel efficiency as a greenhouse gas reduction strategy. The salient effort that has been made is the labeling of vehicles according to their EPA MPG rating. However, little effort has been made to present differences in MPG as anything more than differences in fuel costs. (Efforts to do so include information on the US DOE's fueleconomy.gov website and the Green Car Guide from the Association for an Energy Efficient Economy. However, each of these must currently be regarded as useful tactical devices awaiting an overall strategy.)

But a number of automobile advertisements in recent months have begun to promote fuel economy and the environmental benefits of vehicles. There is something of a brand race on to be the environmental leader in the auto industry; a sense among automobile companies that some consumers are more interested in fuel efficiency and environmental aspects of vehicles than in the past. This change may have been initiated or at least pushed along by the California ZEV mandate in the 1990s. Requirements to manufacture and market ZEVs raised the bar on vehicle cleanliness, bringing the first emission-free and near-zero emission vehicles to some fleet customers and a small number of California households. Automobile manufacturers approached this experiment with caution. They were uncertain of the potential consumer value placed on these attributes and worried that the technical limitations of battery electric vehicles and their higher costs were severe barriers to purchase for anyone but wealthy, committed environmentalist. This latter worry was echoed in their arguments against the ZEV mandate and resulted in very limited efforts to promote battery EVs. The automobile manufacturers placed only a few very targeted advertisements in print media aimed at environmental groups.

Green marketing—the promotion of products based on environmentally superior (or at least environmentally less deleterious) attributes—of vehicles and brands has accelerated with the relative success of hybrid vehicles. Both Honda and Toyota have been airing prime time television advertisements featuring their entire line of vehicles, emphasizing their hybrid vehicles, as well as buying billboard and print space. The new-model 2004 Toyota Prius continues trends by garnering lots of attention, awards and larger than expected sales.

In addition to green marketing, a number of government and private groups interested in clean air and climate change issues have begun “social marketing” aiming to change the behavior of consumers. The best-known example of this is the promotion of hybrid vehicles by actors and celebrities. Some groups have also engaged in negative, anti-gas guzzler social marketing as well, including religious activists who started the “What would Jesus Drive?” campaign and political personality Ariana Huffington who have attacked SUVs. We have been surprised in ongoing household interview work we are doing on the topic of fuel economy at how much effect this “anti-SUV” sentiment might be having among some car and truck buyers. Although we do not initiate discussion of SUVs, many of our interview subjects bring up the “SUV issue.” Some of those with SUVs feel slightly defensive or sheepish about their SUVs, and some of our interview households express strong “anti-SUV” opinions. Perhaps as it is with political campaigns, negative campaigning works.

Green and social marketing are still relatively new to automobile companies. Until recently, most improvements in vehicle emissions and fuel efficiency have been achieved through regulation, not market mechanisms. “Green buyers” were not represented in any of the conventional market segmentation models. But in the last couple of decades, many marketing and consumer research firms have been developing green marketing techniques and re-segmenting their demographic models to include “green market segments” (for two recent models see NEETF/Roper 2001 and Zook *et al* 1999). SRI did pioneering work in the 1970s in this field with its Values and Lifestyles (VALS) model. Turrentine (1994) provides a history of green marketing and marketing of automobile innovations up to 1993. For more detailed discussion of social science approaches to green marketing and social marketing of vehicles see Kurani and Turrentine (2002).

The relationships between consumers, global climate change, and fuel efficiency are more incipient in green and social marketing than are clean air and clean water. In part, this is because the role of transportation emissions in global climate change is unknown to most Americans. However, polling data by Roper, Wirthlin Worldwide, and others have begun to measure changes in Americans knowledge and beliefs about climate change. While the connections between political beliefs and consumer behaviors are not well understood, we can expect that political belief and knowledge are probably necessary initial conditions for green and social marketing to succeed. We cover in some detail relevant knowledge, attitudes, and beliefs of

Californians and Americans in Appendix A of this report. Such knowledge, attitudes, and beliefs are the leading edge of changes in the marketplace and are indicators of the will of citizens.

2.1.5 Recent consumer research at ITS Davis

We are in the midst of completing new research at ITS-Davis on fuel economy decisions by households. With support from the Department of Energy and the Energy Foundation we are investigating very fundamentally whether and how car and truck buyers consider fuel efficiency and fuel economy in their beliefs, behavior and decisions. In contrast to previous research, we are making few assumptions about the role of fuel economy and efficiency in purchases. Rather, we are interviewing households in a basic, open way about their beliefs, habits around use of fuel, and whether and how issues of fuel economy and efficiency shape their vehicle (and fuel) purchase decisions.

Most past research has assumed that consumers make decisions about fuel economy, know the MPG of their vehicles, and have a basic understanding of fuel costs. Our past work with alternative fuels and electric vehicles had raised questions for us about these assumptions. We had interviewed many consumers who seemed not to know the MPG of their vehicles or other vehicles and had not done any calculations of fuel costs. Most knew at most the current cost of a tank of fuel for their vehicles. We thought this was probably because gasoline was a second order expense for most households, lower in importance than, for examples, home ownership, vehicle purchase and financing, and schooling for children. Certainly, a marginal expense for gasoline, between vehicles with different MPG ratings is only a few dollars per week compared to escalating purchase, insurance, and finance costs. Additionally, we had heard anecdotally from automobile dealers that fuel economy was a post-purchase concern of vehicle buyers; some buyers were upset about fuel costs after making a vehicle purchase, but paid no attention to fuel economy before the purchase. Finally, some researchers, particularly from the automakers, have reported that consumers will want a specific payback period on increased costs from improved fuel efficiency.

We have therefore designed detailed household interviews. Our goal in these interviews is to examine in great detail consumer knowledge, beliefs and behaviors relative to fuel economy. We are completing two-hour household interviews; the final count will be between 57 and 60 households. Our sample includes households who recently purchased (or are considering to soon purchase) a new or used car or truck. Additionally, we have selected households from several "sectors"; including farmers and ranchers, graduating college students, computer hardware and software industry, state government resource agency personnel, off-road vehicle enthusiasts, outdoor recreation businesses, military personnel, and financial services. With each household, we review their full history of car buying and ownership, most recent purchase process, the role of fuel use in daily travel, habits, and budgets, and finally, the role of fuel efficiency against other considerations.

While this work still being completed, we have made two presentations on this research and cite these presentations. We will be reporting fully on this research in the coming months. We expect of have completed interviews by the end of April 2004.

3 Consumers, fuel use, and vehicle purchase behavior

In the following section, we review studies about consumers, fuel efficiency, and fuel economy. These studies have focused upon understanding and in particular measuring in some way the importance of fuel efficiency and economy to car buyers. Some studies have tried to estimate consumer willingness or lack of willingness to pay for fuel economy and the importance of fuel economy relative to other attributes of cars.

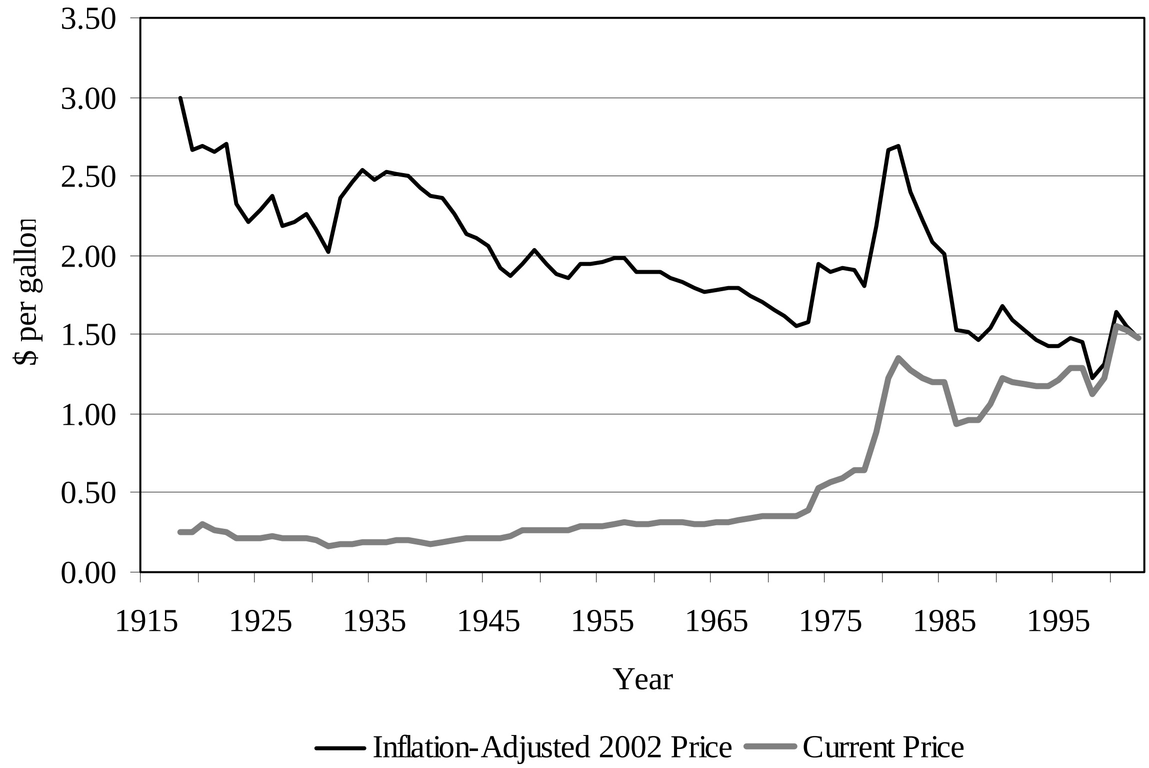
Researchers studying home energy use have been researching homeowners and their energy expenses far longer than vehicle energy researchers. One of the strongest findings from the study of homer energy use is that consumers are ignorant of the issues and calculations surrounding energy use. In a review of consumer behavior around energy efficiency and economy for buildings, Lutzenhiser (1993) reviews numerous studies that show distortions across the population in understanding energy use. These distortions result in poorly informed decisions and maladaptive behaviors. For example, homeowners consistently overestimate potential energy savings from minor conservation behaviors, fail to know the relative amount of energy used by different appliances, and in general do not do any energy accounting. This lack of knowledge and accounting results in optimistic and unrealistic consumer estimates of payback periods for things like energy-efficient refrigerators, water heaters, and air conditioning.

3.1 History of car and truck buyers and fuel costs

During the past 100 years, the cost of driving a mile relative to the cost of other goods has remained remarkably similar. In the mid-1920s, Americans prospered and many bought their first cars. Gasoline, in 2002 dollars, averaged $2.23 per gallon. The Model T, an economical vehicle for its time, got 20-25 miles to the gallon, had a 22.5 hp engine, weighed about 1,350 lbs., and cruised at 35-45 mph. American's didn't drive as much as they do now, or as fast, and roads were still mostly unpaved. And yet, the fuel cost to drive a mile then was similar to today, though perhaps a bit more expensive. While gasoline costs per mile have declined over the past 100 years, the average annual miles driven, cargo needs, and speed demands have grown tremendously. And as incomes have climbed, Americans have bought more vehicles per driver. Vehicles have gotten bigger, more powerful, more reliable, and have added sophisticated mechanical and electronic systems such as air conditioning and power steering that use energy. Perhaps the only instance of "downsizing" in vehicles in the U.S. came with the fuel shortages in the 1970's, followed by inflation and a higher real cost of gasoline, about $2.29 per gallon in 1980 and 1981 (2002 dollars), a real cost not seen since 1939. The spike in real costs of fuel in 1980 can be seen in chart below, accounting for a real shift in fuel costs at that time.

Other nations have not always had the combination of low gasoline prices, growing incomes, expanding interstate highway system, and poor transit that resulted in so much automotive fuel use in the United States. In particular, in the post-WW II era European and Japanese automakers made small, economical vehicles for their working classes. Gasoline was taxed heavily in all these nations. When the oil shortage hit in the 1970s, small, economical vehicles from Asian automakers made big gains in the U.S. market, as US consumers responded to both actual shortages and higher prices. Fuel-efficient mid-sized sedans from Asia and Europe and diesel-powered Mercedes-Benz cars took market share from American luxury vehicles as well.

Figure 1: History of U.S. Retail Gasoline Prices, Current and Constant 2002 Dollars



Sources: American Petroleum Institute, Basic Petroleum Data Book, Washington , D.C.; US Dept. of Labor, Bureau of Labor Statistics; and US Energy Information Administration, www.eia.doe.gov

Over the 1980s, the cost of gasoline per mile for an average light vehicle dropped from its high in 1980 of around 10 cents per mile back down to under 6 cents per mile in 1987, where it stayed throughout the 1990s (Davis, 2003). The price of gasoline has stayed low for many years while purchase price, depreciation, insurance, and maintenance costs have risen. Therefore fuel economy has not been as important to car buyers as it was in the 1970s and early 1980s. As gasoline prices dropped in the 1980s, American automakers responded by marketing larger vehicles with truck-like designs and bigger engines. The primary trends in US vehicle markets since the oil shortages of the 1970s have been the rapid growth of market share for minivans, SUVs, and pick-up trucks pushing sales of truck-based vehicles from less than 18 percent of the market in the late 1980s to over 50 percent by 2001. These larger, heavier, less aerodynamic, and often 4-wheel drive vehicles have lowered average fuel economy of the U.S. automobile fleet.

On average, depreciation of vehicles in the U.S. rose from 27 percent of the cost of owning and operating a vehicle to 47 percent between 1985 and 1999. In 1985, gasoline and oil were 23 percent of annual motor vehicle costs, and were the second biggest category of costs after depreciation. The cost of gasoline and oil have since dropped to 10 percent of annual costs (in 1999), and ranked fourth behind depreciation, insurance, and financing (Davis, 2002). Against this financial backdrop, marginal changes in fuel economy make less difference to the cost of owning and operating a motor vehicle.

Automakers have told regulators that there is little they can do to get consumers to buy more economical cars. They argue that because gasoline has been cheap, they have designed—and car buyers have chosen—larger, truck-like, and more powerful vehicles. And because fuel economy has not been that important, it has not received much attention until quite recently from automotive researchers looking at vehicle purchases. Yet despite seeming widespread consumer indifference to gasoline costs when purchasing a vehicle, consumers invariably complain whenever gasoline prices go up a few cents—enough so that television news stations send a reporter to the gas stations with every price jump to interview vehicle drivers refueling their vehicles. But for the most part, fuel costs have stayed low in comparison to other vehicle costs, and have not had a big impact on consumer purchases and travel behavior, except among the lowest income buyers. In the last three years, the price of gasoline has increased some, there are wars in the Middle East, and some of the public is aware of global warming concerns about fuel use. The launching of hybrid vehicles into the market may signal an interest in fuel efficiency, but it is early to be certain of the extent and impact of this interest.

3.1.1 The history of consumers response to changes in vehicle prices due to regulatory changes

The question of how consumers responded to changes in vehicle prices implies that regulations have raised the cost of vehicles, resulting in higher prices and further, that consumers have responded in some way to those price increases *due to regulation* as opposed to price increases due to other causes. Our main observation here is that the price increases due to emissions, safety and fuel economy regulations are overshadowed by other price variations in the market and the comparative relative *decline* in the costs of cars and trucks as compared to other goods and services. The question of how consumers respond to price increases caused by regulation makes sense only in an abstracted *ceteris paribus* way, but makes little sense in the real car-buying world, where all else has not been equal. The market has grown from several hundred to over 1,000 makes and models. Buyers are confronted by greater variation in prices between body styles, brands, trim packages, dealerships, rebates, financing options, options packages, warranties, yearly increases in prices and other options like four-wheel drive, etc. The question of how consumers respond to price increases caused by regulation makes little sense in a world where consumers don’t evaluate vehicles by single attributes, but evaluate suites of attributes. Regulations designed to affect one vehicle attribute may affect consumers in unexpected ways, as consumers evaluate the suite of attributes to which the regulated attribute belongs. The question of how consumers respond to price increases caused by regulation makes little sense in a world where prices convey more information than simply private cost.

Implicit in the question of how consumers respond to price increases caused by regulation is idea that the cost of vehicles to households has risen. This initial premise is at best arguable, if not demonstrably false when we ask “compared to what?” Expenditures on vehicles have declined as a share of aggregate consumer expenditures, while at the same time the number of vehicles sold has increased, the number of vehicles per household has increased, and the number of vehicles per household member has increased. In short, in comparative terms over time, Americans have been buying more vehicles and spending less of their income and time to do so. Over the time period of the analysis below, vehicles have also incorporated more safety equipment, more emissions controls, gone through periods of advancing and declining fuel economy, become more powerful, larger, heavier, incorporated more amenities such as air conditioning, improved reliability, and reduced maintenance requirements.

Data from the US Department of Commerce's Bureau of Economic Activity demonstrates that on a current dollar basis, expenditures on new and used motor vehicles declined from 1959 to 2000 (Moran and McCully, 2001). In current 1959 dollars, purchases of new cars and trucks by households accounted for 4.2 percent of all *personal consumption expenditures*.[3] The share for autos was 4.1 and for trucks, 0.1. By 2000, the overall share of personal consumption expenditures in current 2000 dollars had declined to 3.1 and the shares for autos (1.5) and trucks (1.6) were nearly equal. Shares for net purchases of used vehicles were similar in both years: 0.9 in 1959 and 1.1 in 2000.

The declining share of current personal consumption expenditure simply means that in aggregate consumers are spending comparatively less in aggregate on new and used cars and trucks than they are for other goods and services. Data on vehicle sales tells us this relative reduction is not because Americans are buying fewer vehicles. In 1959, Americans bought 7,065,000 new cars and trucks (AAMA, 1995). In 2000, they bought more than twice as many: 17,234,000 (Davis and Diegel, 2002; Tables 7.5 and 7.6) In fact, the year 2000 was the unprecedented fifth year in a row that combined sales of new cars and light-duty trucks topped 15 million units. This increase in the number of vehicles sold means that while aggregate expenditures for new and used cars and trucks declined as a share of total personal consumption expenditure, households bought more vehicles. The per capita number of vehicles in operation increased from 0.37 in 1960 to 0.78 in 2000 (Davis and Diegel, ibid, Table 11.2).

The implied high level of household vehicle ownership from such aggregate statistics is shown to be real by looking at more disaggregated data. For example, the share of US households who own more than three vehicles has increased from only 2.5 percent in 1960 to 18.3 percent in 2000. Despite the increase in quality, reliability, size, weight, performance, safety, efficiency, and emissions controls for cars and trucks, the total share of personal consumption expenditures for new and used cars and trucks declined over the forty-year analysis period.

3.1.2 Historical data on safety and emissions costs from the 1980s and early 1990s

Greene (1992) discusses data from the Bureau of Labor Statistics and additional data cited in the American Automobile Manufacturers Association's (AAMA) *Motor Vehicle Facts and Figures 1991* for the years 1971-1989 on average household expenditure per new car and adjusted average expenditure per new car based on regulated safety, fuel economy, and emissions improvements to vehicles. The conclusion he presented was that these regulations resulted in about a 20 percent increase in average expenditure per car in current dollars. (All dollar figures in this discussion are current dollars for the year in which the data are cited.) The data do not include trucks, which have not been subject to identical safety and environmental regulations

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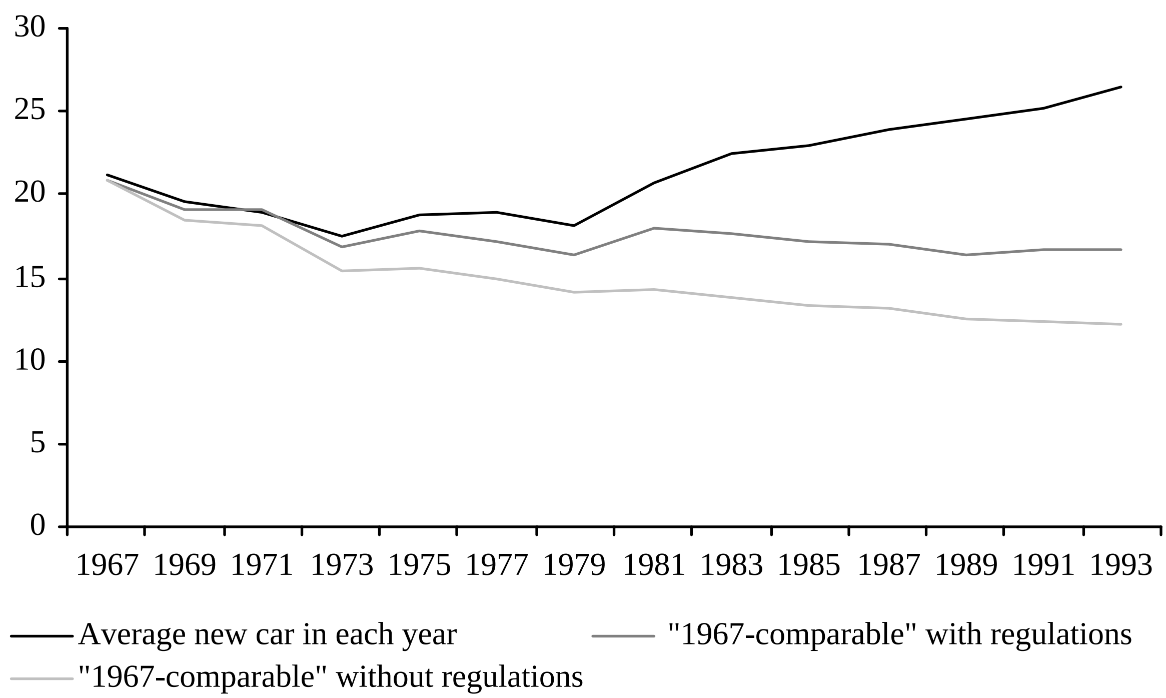
[3] Personal consumption expenditure includes expenditures by US citizens abroad, including civilian and military personnel. It also includes imputed values for rents and services. While the Bureau of Labor Statistics consumer expenditure survey data (which excludes these things and more directly measures out-of-pocket expenses) might be preferable, we use the Bureau of Economic Analysis' PCE because other data used by the American Automobile Manufacturers Association cited in this review are based on the PCE data.

over the time period he analyzed. Importantly though, truck sales have grown to more than half of the current market for new light duty vehicles. Maybe more importantly, the data are not specific to California, but are national.

But perhaps most important is that the average expenditure per new car has grown far more than the 20 percent attributed to safety and environmental regulations. The average buyer is buying much more luxurious, higher quality, more reliable, and more powerful cars and trucks than they did in 1967. (1967 is the base model year from which expenditure increases are calculated.)

We update slightly the data Greene (ibid) used using *Motor Vehicle Facts and Figures 1995* (AAMA, 1995, p. 60). The data on the number of weeks a household earning the median income in each year would have to work to pay for cars are plotted below. The average household expenditure in 1993 for a "comparable 1967" car without the regulated safety, emissions and fuel economy improvements would have been $8,631. This would have required 12.2 weeks of median household income to buy. The average transaction price of a new "comparable 1967" car with regulated safety and environmental improvements would be $11,806 and take 16.7 weeks of median household income to buy.

Figure 2: Number of Weeks a Household Earning the Median Income in each Year would have to Work to pay for the Average New Car.



The 1967 Comparable Car with Safety and Emissions Improvements, and the 1967 Comparable Car with out Safety and Emissions Improvements

This difference in average expenditure ($3,175) was a considerable “price” increase, however it is nowhere near the whole story. The actual average household expenditure on a new car in 1993 was $17,549, and required 26.5 weeks of work. This shows that consumers have on average upgraded their cars in many ways, i.e., they have chosen much more expensive vehicles than the average 1967 car. If you were to look also at trucks (including SUVs, vans, and minivans,) you would see even greater purchase power and flexibility in choosing what were luxuries in the 1960s, such as air conditioning, power accessories, elaborate sound (and now, video) systems, etc. The chart illustrates that two-thirds of the increase in the average expenditure for the price of a new car from 1967 to 1993 had nothing to do with regulated increases in safety and emissions control.

Our claim that the cost of automobiles declined from before the OPEC oil embargo of 1973 and well into the 1990s is bolstered by looking at the time it takes households to earn sufficient income to buy a new car. The analysis illustrated in Figure 1 indicates that even with safety and environmental regulations, the amount of time it would take a household earning the median income to buy the average new car declined from 1967 to 1993 by about one month. We note further that the “1967 car without regulated improvements” is an arbitrary datum and can in no way be interpreted as an ideal state that might have actually been perpetuated in the absence of government regulation.

The increase in the average expenditure for new cars was not accommodated entirely by proportionate increases in household incomes. Greene (ibid) cites evidence that in real terms household income increased little if at all over the period he analyzes. Increased expenditures on new cars were financed by longer-term loans. As Greene concludes, “Because of an increase in the maximum possible length of the term of the loan (from four to five years) in the early 1980s, the average monthly payment has not gone up as rapidly as new-car prices.” (Greene, ibid. p. 110). Data from the 1995 edition of the AAMA’s Facts and Figures show that the average term of a new car loan increased from less than four years (45.0 months) to four-and-one-half years (54.1 months) from 1980 to 1994. Greene’s reasons for why the term of loans have increased represent an optimistic view of the functioning of the market.

> “The maximum loan period is market driven, that is, it is associated with the rate of depreciation for the automobile, which in turn is influenced in part by its lifetime, and durability and the demand for the automobile in the used car market.” (Ibid, p.110)

An alternative explanation is an intentional effort by the automobile industry to sell more expensive vehicles by offering longer term financing. This view is supported by our ongoing series of household interviews regarding vehicle purchases and by survey data. Many households shop for vehicles based primarily on the monthly payment they believe they can afford rather than the total purchase price. Kelley Blue Book (2003) reports that 20 percent of people shopping for a new vehicle “plan to negotiate based on the monthly payment.” A longer-term loan is one-way to sell a customer a more expensive vehicle while holding the monthly payment constant.

Over the time period of 1967 to 1992, consumers have clearly demonstrated they will pay considerably more for vehicles, both for “regulated” safety and emissions improvements, as well as for luxury, quality, reliability, performance, and size. The missing data for this analysis are comparable data for light-duty trucks. A complete accounting of the effects of safety and emissions regulations on car sales would have to address the degree to which the shift of the new vehicle market towards trucks was driven by more lenient safety, emissions, and efficiency regulatory treatment that allowed lower manufacturer costs.

3.1.3 Econometric analysis of household response to higher gasoline prices

The economic literature on household response to higher gasoline prices tends to focus on the issue of elasticities—how much does fuel consumption, vehicle miles of travel, or household fleet fuel economy change for a unit change in the price of gasoline? Pitts, Willenborg, and Sherrell (1981) set out to examine "how persons have reacted to the increasing price of gasoline in an environment of perceived shortages." (The time period of their analysis is 1973 to 1979.) They state, "Economic principles lead us to believe that increasing prices of gasoline would decrease demand." From this point they characterize the possible strategies for reducing fuel consumption in the face of higher gasoline prices, i.e., "…consumers could cut back on their driving, buy more efficient vehicles, seek the lowest-priced gasoline, increase relative usage of the more efficient vehicle(s) in multi-vehicle households, drive at reduced speeds, or do nothing at all."

Pitts, Willenborg, and Sherrell (ibid.) group households into a two-by-two matrix according to whether or not they reduced or made no change to miles driven and reduced or made no change to the average number of engine cylinders in the household stock of vehicles during the period of analysis. (Number of engine cylinders is used as a proxy for fuel economy.) They conclude that membership in any particular group is determined by both demographic variables—such as race, household size, and years of formal education of the household head, values—such as desire for a comfortable life, an exciting life, and family security. Price sensitivity—measured as an attitudinal variable—did not explain adaptive behaviors in response to higher gasoline prices. More specifically, they conclude, "Generally, gasoline price increases do not discourage driving—except among specific segments whose financial condition will not accommodate the higher prices."

This conclusion, that higher gasoline prices (at least within the range of price variations within the available data) do not result large reductions in travel, i.e., travel demand with respect to gasoline fuel prices is relatively inelastic, is repeated in other studies. Kayser (2000) concludes, "Higher gasoline prices will not lead to a substantial reduction in the amount of gasoline consumed by households in the short-run." Puller and Greening (1999) conclude their analysis produces results "consistent with the literature and support the claim that gasoline demand is relatively inelastic in the year following a [gasoline] price change." They decompose demand for gasoline into demand for travel and for the fuel economy of that travel. They find, ironically, that in the face of higher gasoline prices, households in the aggregate reduce *both* miles driven and the fuel economy of the remaining travel—on average, households travel fewer miles, but consume more gallons per mile for the remaining travel they do undertake. The authors offer the suggestion that households reduce higher economy highway travel more than they reduce lower economy local trips.

3.2 Vehicle owners: knowledge and calculation of fuel economy

Throughout this section we will explore the extent to which consumers may be plagued by similar mistakes and gaps in knowledge about fuel use in their vehicles as they are in their homes. In an on-going series of household interviews, we have found that consumers have limited knowledge of their vehicle's fuel economy and monthly or annual fuel costs. When we ask these questions, most householders "confess" they probably should know, but have no idea. Perhaps the pieces of knowledge about fuel costs known by most drivers are the price of a gallon of gasoline and the price of a tank of gasoline. These are numbers they encounter weekly, and are shown plainly on pumps and signs, receipts and credit card statements. In a 1999 study for National Renewable Energy Laboratory study conducted by Opinion Research Corp. International (ORCI), out of 1,000 adult American car buyers asked about the fuel economy of their most recently purchased vehicle:

- 26 percent said "fuel economy was not an issue,"
- 22 percent said they saw the fuel economy on the window sticker when they bought the car,
- 12 percent saw the mpg in a dealer brochure,
- 11 percent found the mpg in a magazine or consumer guide,
- 5 percent heard the mpg by word of mouth,
- 4 percent on the internet,
- 2 percent on television,
- 1 percent in a government fuel economy guide
- 18 percent said they didn't know or don't own a vehicle.
  (Gurikova, 2002)

One reason for the lack of knowledge and perhaps indifference to fuel economy is that most vehicles have only primitive instrumentation for tracking fuel use, such as analog gasoline gauges, as well as odometers to measure distance driven. Only a few vehicles have instruments that show the driver real-time average or instantaneous MPG or have onboard computers to help drivers track fuel use over time.

In our most recent interview work, we are exploring the impact of these instruments on consumer awareness of fuel costs. Because of the general lack of accurate energy instrumentation, knowing a vehicle's MPG requires reading the owner's manual or doing some recording of fuel use and simple math. We have found that almost no one includes fuel costs in household budgets. However, some drivers who use petroleum company credit cards do see monthly and even annual summaries.

In previous detailed household interviews we did on markets for electric vehicles, we found only a minority of drivers knew the driving range and MPG of their conventional vehicles (Turrentine and Kurani 1995). These tended to be technically oriented consumers, such as engineers, who routinely calculate MPG. We found that few drivers know annual fuel costs, except those who are in business, and therefore keep track of expenses for reimbursement or tax purposes. Some of these also use the odometer to calculate when to refuel instead of their gasoline gauge. A few consumers we have interviewed calculate MPG on longer trips or if they have longer commutes.

The point here is that there is a wide distribution of consumer fuel cost accounting behaviors, from those who are highly informed to those who keep no records and do no calculations of fuel economy. This has a profound effect on consumer consideration of fuel economy.

Of all aspects of fuel economy, drivers are most aware of pump prices, the cost of a full tank of gasoline, and in some cases can offer estimates of average weekly or monthly fuel costs relative to how often they think they filled their tank in previous months. In part, pump price is also quite volatile, thus it gets lots of attention in the press. A rise in the price of gasoline of ten cents per gallon can get significant press, despite that such might result in only an increase of only a few dollars in weekly costs per vehicle. For this reason, pump costs and prices have a disproportionately large effect on consumers' consideration of fuel economy.

Past studies have shown that, for example, decisions about purchases of light-duty diesel vehicles was most affected by pump price of fuel as opposed to annual fuel costs or any other cost measure (Kurani and Sperling, 1991). Marginal increases in gasoline prices have minimal impact on total consumer expenses, and yet get much attention from car owners, though as we have noted, that attention is seldom expressed as reductions in daily travel.

We are hypothesizing, based on preliminary results from on-going interviews with households regarding fuel economy and efficiency, that car and truck owners may overestimate how much they spend annually on gasoline, in part because their primary source of information about their fuel expenses is the pump price or the cost of a tank of fuel, and because they are more likely to notice and recall price increases than decreases. This hypothesis is in keeping with findings about home energy use. In summary, because of the decreasing cost of fuel in driver budgets, the overall increase in fixed costs of vehicles, and the lack of instrumentation, consumers do not manage adequate information about fuel economy to make rational choices. Most importantly, few consumers know their annual fuel costs; they react mostly to pump prices and per tank costs. Even if car and truck buyers understood annual fuel costs, the low cost of gasoline might mean less interest in fuel economy.

3.3 Fuel economy and trends in consumer choice for new vehicle attributes

It has become common practice in the automobile marketing research industry to ask consumers to "rank" the relative importance of lists of aspects, features, or attributes of vehicles in their choices. Attribute ranking studies by major research groups such as Maritz, J.D. Powers, and Auto Pacific have often found their way into popular press, replacing past studies that focused on brand and model preferences. These ranking studies have featured prominently in the debate between vehicle makers and government regulators over CAFE standards. Perhaps most infamous is an oft-repeated quote about a study mentioned in the Los Angeles Times on March 29, 2000 reporting automobile shoppers ranked fuel economy lower than cup-holders. More recently attention has been on consumer rankings for safety, towing, four-wheel drive and other attributes of SUVs. Econometric analyses take this same individualized attribute approach—consumers buy vehicles essentially as amalgamations of individual attributes—and study the value consumers have for the particular combination and for individual attribute. Most significantly, safety and reliability have risen steadily in consumer purchase consideration over recent years.

In its discussion of fuel economy and consumers, the Alliance of Automobile Manufacturer's website cites a 2000 Consumer Preference Research by Maritz Marketing that "ranks" a large list of vehicle attributes. Reliability is listed as number one, safety number six, power and acceleration number sixteen, quietness number nineteen, and fuel economy number twenty-five. Mark Thibault of GM discusses the ranking of fuel economy in his report to the National Academy of Sciences, noting that in a long list of questions asked at a consumer clinic, "I will purchase only a vehicle with good fuel economy" was number 65 on the list, and "Greater Fuel Economy/Less Performance" performance, dropped to number 99.

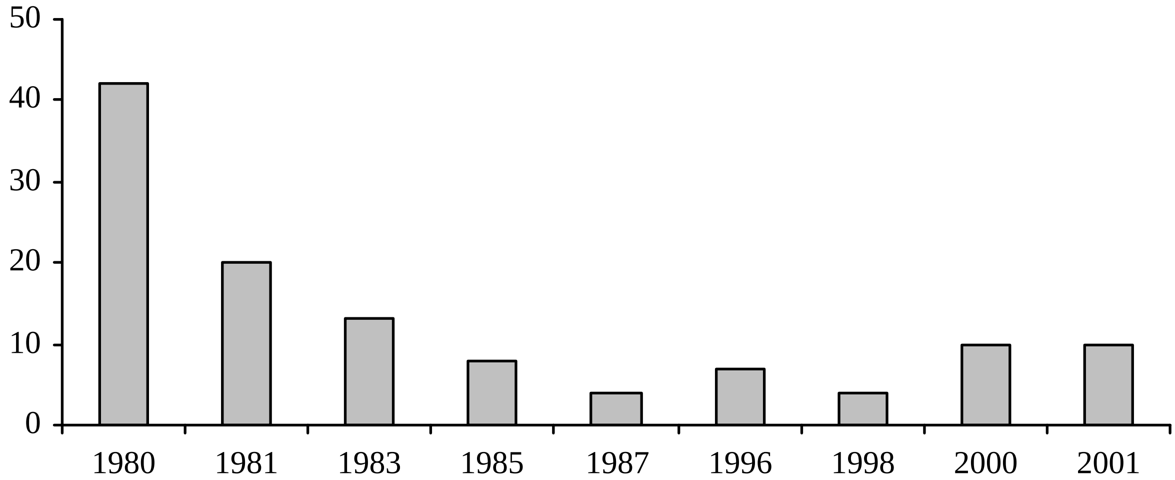
But simple attribute rankings overlook the different ways in which attributes of vehicles can impact consumer choice processes. Consumer choice processes may consist of a number of steps, including initial shopping behavior in which consumers form initial consideration sets of vehicles, but also a subsequent step in which options are narrowed. Along these lines a 2003 J. D. Powers "Escaped Shopper Study" asked, "for which reasons did car buyer reject a particular model." That study reported that in 2003 gasoline mileage had moved up to 5th reason consumers rejected one model over another, up from 13th in their 2002 study (Daily Auto Insider, September 2003). Below is the list of top ten reasons from that study why people rejected a particular vehicle.

1-Total price too high,
2-Total monthly payment too high,
3-Didn't like exterior design,
4-Didn't have rebates or incentives that the ultimate choice did have,
5-Wanted better gas mileage,
6-Concerned about reliability,
7-Not available with low interest financing,
8-Didn't like look/design of interior,
9-Salespeople didn't act professionally,
10-Vehicle was too small.

Consumers go through a post-purchase "consumer satisfaction" phase as well, in which they evaluate how good a selection they made. In this phase they may shape their future choices and influence other buyers. Automobile sales people have told us that good fuel economy does not "attract" buyers, but rather is a "post-purchase" attribute that shapes initial consumer satisfaction in the months after purchase.

Also, the ranking of fuel economy may be shifting in the last few years; the Maritz study cited above may have measured indifference to fuel economy at its height (or depth, depending on one's perspective). A U.S. Department of Energy review of several 1980's studies by J.D. Powers and later studies by Opinion Research Consumer Insights, shows how fuel economy was important in the early 1980s, dropped in the 1990s and has risen a bit in the last few years.

Figure 3: Americans who say they considered fuel economy in their last vehicle purchase, percent.



Source: Gurikova, 2002.

In a survey of 1,000 adult American car and truck buyers, an ORCI 1998 survey reported found the following "things" that would motivate buyers to purchase a more efficient vehicle in an open ended question "For your next vehicle purchase, what would motivated you to buy a more fuel efficient vehicle?" (cited in Gurikova, 2002).

- 428 said they would be motivated if there were cost savings (159 lower sticker price, 130 said lower costs in general, 121 said lower cost of fuel, 43 said other cost savings)
- 219 said they would be motivated by features and performance attributes (104 said less pollution and acceptable emissions, 33 said hp and speed, and 99 said other features/options)
- 167 said they would be motivated by the fuel efficiency/gas mileage
- 46 said they would be motivated by availability of the type of fuel needed
- 105 said "other"
- 74 said "not interested"
- 87 said "don't know"

This open-ended question reveals a complicated set of responses. Only 74 persons rejected fuel economy outright, the majority of respondents were interested in some sort of cost savings, a smaller number in other features, and 167 who essentially echoed the question.

3.4 Willingness to pay for better fuel economy

It is of great interest to regulators and car makers to predict whether and how much consumers will pay for technological advances that enhance fuel economy and efficiency, technologies such as light weight materials, continuously variable transmissions, low rolling resistance tires, or more complex technologies such as hybrid electric drive trains.

Automobile buyers are not accustomed to paying more for higher fuel economy; higher fuel economy has until the advent of hybrid drive trains been a feature of lower—not higher—cost vehicles. If consumers wanted higher fuel economy, they bought less expensive four-cylinder engines rather than the six cylinder engines, or six rather than the eight. They bought smaller vehicles rather than larger ones. They bought manual transmissions rather than automatics. They bought two-wheel drive rather than four-wheel drive. Higher fuel economy has not been marketed as an attractive feature in many years. Except for recent hybrid vehicles and some diesel-powered models, the differences in fuel economy between most comparable gasoline-powered models are only a few miles per gallon. For example, according to the EPA estimates a Honda Accord gets three to four miles per gallon better fuel efficiency than a Ford Taurus—a direct competitor in the midsize sedan category. If consumers were to calculate their annual savings based on such a difference, it would be between one and two percent of the annual cost of owning and operating the vehicle. There are greater differences between vehicle types, such as between a midsized sport utility and a midsize sedan, which can approach three to four percent of the annual cost of ownership and operation, depending on the annual miles driven.

But, as we noted above, most consumers probably do not know their annual costs, per mile costs, or other measures of fuel costs. They *might* know the MPG of their different vehicles (our interviews reveal many don't) and might read the EPA labels when shopping (our interviews indicate few do). Moreover, obvious differences in upfront vehicle prices are likely to overshadow future fuel cost savings and maybe other concerns related to fuel consumption. Additionally, many of the options consumers seek, such as good acceleration, ability to tow, perceived safety, automatic transmissions, air conditioning, four-wheel drive, large cargo space and interior room decrease fuel economy, and thus conflict with and also overshadow marginal improvements in fuel economy.

However, based on the issues discussed above and results of our recent interviews with households, we believe measuring willingness to pay for fuel economy is currently a problematic research direction. Since they have not been faced with the reality of paying more for higher fuel economy, consumers might only have enough sensibilities about MPG to respond to close-ended prompts (such as "would you pay $500, $1000, or $1500 for better fuel efficiency?") or to offer some dollar amount off the top of their head. But their answers to such questions will not be based in how they behave when they purchase a vehicle; inferences from such questions should not be made in literal dollars and cents. For example, ORCI asked the following question was asked for NREL in a telephone survey of adult Americans: "How much more would you pay for a vehicle that gets 10 percent better fuel economy?" Responses from the 180 respondents are summarized below. The results might appear encouraging; nearly four of ten respondents indicate they would pay more than $1,000 more for a vehicle with ten percent better fuel economy.

We are more cautious in our interpretation of such results. We ask a similar question in our current interview work and find that many of our respondents are not telling us how much they would be willing to pay. Rather, they are trying to estimate how much they thought such improvements might cost, or are trying to answer in a way that seems to them to be "reasonable." In fact, most reveal they have no way of knowing how much they would be willing to pay.

Figure 4: "How much more would you pay for a vehicle that gets 10 percent better fuel economy?"

Dollar Amount	Percent
None	18
<$500	7
$500-1000	15
$1001-2,500	17
$2,501-5000	15
>$5000	5
Don't know	23

N = 180.
Reported in (Gurikova, 2002)

Over the years, we have studied the potential market for electric vehicles and other automotive technologies, interviewing hundreds of Californians in their homes, and surveying additional thousands through telephone, Internet, and mail-back surveys. We have noted in several instances that responses by consumers gravitate to what we call "magic numbers" (Turrentine and Kurani 1995). For example, with electric vehicles we often found that a large percentage of our households, when asked how much range they wanted, would initially say "100 miles," regardless of their needs. We had to dig deeper to find a more informed answer—100 miles was a simple, initial answer to a complex and novel question.

We see evidence of these "magic number" responses in other studies too. In household interviews or focus groups, large numbers of participants will routinely answer with a "magic number" such as "$1,000" or "$2,000" as an incremental amount they would be willing to pay for a new technology (and environmental benefit) they are being asked to consider. Also, focus group moderators and survey questions often prompt respondents with a range of big, round numbers, e.g., $500, $1000, $2000, $5000. Often the largest number of proffered response is $1000 or sometimes $2000. We see these ranges offered regardless of the technology being researched, whether it is a hybrid electric drive system, a battery electric vehicle, a CNG vehicle, or clean diesel.

We suspect these magic numbers are not measures of actual "willingness to pay" but rather are simpler, almost a yes/no response—high amounts are "yes" and zero or low amounts are "no." When consumers are being asked to consider a new technology such as hybrid drive train, or improvement such as better fuel efficiency/economy, or a social benefit such as lower emissions of criteria pollutants or greenhouse gases, we argue a “willingness to pay $1000” must be read by researchers as an agreement by the respondent that the technology seems beneficial, and there will be some willingness by the respondent to pay. Alternatively, they may be saying $1,000 is a reasonable price increase for a new car incorporating the new technology—regardless of whether they would pay this amount. In general, we are finding in our own work that the distribution of answers in willingness to pay surveys—especially for novel services and technologies—are complex, and if you look in greater depth, you find many consumers are guessing, uninformed, overly optimistic, or in some cases answer with what they think is the right answer—not what they personally would be willing to pay. Still, they are likely signaling that they may favor the new idea, or at least are interested in more information.

3.5 Trade-offs of fuel economy with other attributes that may flow from increased fuel efficiency

Safety, four-wheel and all-wheel drive, and towing packages for trucks are three vehicle attributes or features that have grown in importance to consumers over the past two decades. The automobile industry has in particular made much of the issue of perceived and actual safety as a function of the size of vehicles. They have argued that CAFE standards will force reductions in size or weight, which will in turn compromise safety. They also argue that consumers value size as a safety attribute. A question asked by ORCI for NREL in 1999 found that 82 percent of the 1,000 adult Americans polled thought a lighter vehicle was not as safe as a heavier vehicle in a traffic accident. Four-wheel drive is another technology added to vehicles that is antagonistic to increased fuel economy. Another question asked by ORCI for NREL, this time in 1998, found that 47 percent of potential pickup truck buyers, 8 percent of potential minivan, 16 percent of potential standard van, and 43 percent of potential SUV buyers planned to use their vehicle off-road (Gurikova, 2002). The sampled consisted of 439 potential light duty truck buyers.

The AAM website cites a 1996 J.D. Powers “Appeal” study that states more than half of light duty truck owners report using their vehicles to tow a boat or trailer. The AAM also quotes the Coalition for Vehicle Choice saying the percentage of passenger cars that are capable of towing 2,100 lbs has dropped from 68 percent in 1978 to less than 6 percent in 2000. The 1998 ORCI study of 439 potential light duty truck buyers, (pg. 47 Gurikova, 2002) found that 52 percent of potential pickup truck buyers, 32 percent of potential minivan, 33 percent of potential standard van, and 51 percent of potential SUV buyers planned to buy a towing package.

Another trend in recent years has been greater power and acceleration, usually to the detriment of fuel economy. A number of studies have examined this trend. Thibault reports on a 1999 GM research clinic, i.e., a market research method in which participants answer a battery of questions, often with vehicles to drive, see, and touch. In the study buyers were offered a range of vehicles with increasing power and price and decreasing MPG. Buyers in the low-end coupe segment and the medium size sedan segment were offered the variety of vehicles summarized below, and asked to rate the vehicles desirability on a scale from one (least desired) to five (most desired).

Figure 5: GM research on consumer desire for power and MPG

Vehicle Description	Average Rating (1 to 5)
"Low-end coupe" market segment	
2.0L, 4 cyl., 125 hp., 28/38 mpg.	2.2
2.2L, 4 cyl.,140 hp, 25/36 mpg.	2.5
2.2L, 4 cyl., 160 hp, 25/36 mpg.	2.8
2.2L, 4 cyl., Turbo 175 hp, 25/35 mpg.	3.1
2.8L, V6, 170 hp, 21/30 mpg	3.5
3.0L, V6, 190 hp, 19/28 mpg.	3.7
"Medium size sedan" market segment	
4cyl., 137 hp, 22/31mpg.	2.6
4 cyl. Turbo, 175 hp, 20/28 mpg.	3.1
6 cyl. 222 hp, 20/29 mpg.	4.5

While it is difficult to interpret these results other than as a measure of "wants," the low-end coupe buyers preferred the most powerful engine even at a higher price and with poorer fuel economy. In a medium-sized sedan segment clinic 0, the desire and willingness to pay for power over economy was even more pronounced.

In contrast to the study above, an NREL study by ORCI gave respondents an option to buy five vehicles contrasting in acceleration, weight, and MPG. Of these three variables, weight is an unconventional attribute, not usually considered a choice attribute, especially when represented as "10% lighter" or "10% heavier." These numbers are probably meant to represent "smaller" and "bigger" and to elicit conventional consumer thinking that bigger is safer. The study showed a sizable group of respondents choosing a lighter, average acceleration, more efficient vehicle. And it is surprising that only 17% consumers would choose 1.5 seconds faster acceleration over $4 a month savings. While unconventional in asking about weight, this study illustrates alternative wording might yield some new insights to consumer values.

Figure 6: ORCI study of consumer choice for power and MPG

Vehicle Description	Percent choosing this vehicle
0-60 in 10.5 seconds, 27.5 mpg	15
Same acceleration, 10% lighter, 2 mpg better (save $4/mo.)	27
1.5 seconds faster, 10% lighter, same mpg,	17
1.5 seconds slower 10% heavier, same mpg	16
Same acceleration ,10% heavier, 2mpg worst (cost $4/mo.)	5

3.6 What can we learn from the Case of Light-duty Diesel Vehicles?

Diesel engines provide somewhat improved fuel efficiency and can provide greater fuel economy than gasoline engines depending in part on whether the diesel vehicle also matches the gasoline-powered versions in power and acceleration. Whether improved efficiency and economy translates to lower fuel cost depends in part on relative fuel prices. Further, diesel engines have typically been offered by a limited number of manufacturers in a limited variety of body styles. Further, diesel fuel is available at only a small number of retail locations compared to gasoline. With these other difference in mind, we review consumer experience with diesel vehicles for clues as to whether people value diesel vehicles higher fuel efficiency and economy.

3.6.1 California, 1970s to early 1980s[4]

Diesel-powered light duty vehicles have long been available in the US, but their greatest popularity to date came during the late 1970s and early 1980s in response to gasoline price increases and supply disruptions. In contrast to the current case in Europe (see the following section), diesel fuel did not enjoy a consistent per gallon price advantage during this time period in the US. It was true that diesel vehicles consistently cost more to buy than comparable gasoline-powered cars and light-duty trucks. Despite a flip-flop in the relative prices of gasoline and diesel fuel, some diesel vehicle buyers could have expected to save on their private fuel costs because of the increased fuel efficiency of the diesel drive trains. Kurani and Sperling (1987) reviewed some specific cases. Those results are excerpted and updated below.

> Based on data published by Oldsmobile engineers regarding the 1978 5.7 liter diesel engine, assuming vehicles are driven 15,000 miles per year, owners of 1979 model year Olds 88s and 98s could expect to wait 47 to 54 months for their fuel cost savings to pay back the additional cost of the diesel engine (Jones *et al*, 1978). A shortcoming of that analysis is the implicit assumption that consumers have a zero time value of money—that is, their implied discount rate for future fuel cost savings is zero.
>
> An analysis of the difference between vehicle purchase price and annual fuel costs for the 1981 model year Volkswagen Rabbit and the Peugeot 505 is given in the table below. It is assumed that the vehicles were driven 13,000 miles per year, diesel fuel was prices 3.6 cents less [per gallon] than gasoline, and fuel price differences remained constant. The results are presented for a range of annual percentage rates (APR). The chosen APRs span a range of relevant values, from the zero percent value of Jones *et al's* (ibid) analysis to a high value still well within the range estimated by Train (1985) and Greene (1983).

[4] This section draws on a case study of diesel light-duty vehicle markets in California in the late 1970s and early 1980s conducted by Kurani and Sperling. We include here updated discussions. The original studies include Sperling and Kurani (1987) and Kurani and Sperling (1987).

Figure 7: Consumer choice for diesel and gasoline

	VW Rabbit	Peugeot 505
Diesel model mpg	40	28
Gasoline model mpg	28	20
Increase in purchase price for diesel model	$425	$1,000
Difference in fuel cost per year (gasoline – diesel)	-$230	-$307
Months for fuel savings to pay back purchase price premium at:		
0 percent APR	22	39
6 percent	24	44
17 percent	27	58
30 percent	33	154

At zero percent APR, e.g., a simple payback calculation as assumed in the Oldsmobile analysis, it would have taken 22 months for the fuel cost savings to pay back the higher purchase price of the Volkswagen Rabbit and 39 months for the Peugeot 505. As future fuel cost savings are increasingly discounted by higher implied interest rates, the payback periods increase—dramatically so in the case of the Peugeot for which annual fuel cost savings were a smaller percentage of the difference in purchase price.

In summary, diesel fuel prices were less than gasoline prices [from 1977] through 1981, and fuel costs per mile were less with diesel fuel throughout the diesel car era [1977 to 1985]. However, by 1983 the full cost of owning and operating diesel cars had increased relative to gasoline cars so that annualized costs were similar for both types of cars. When, if ever, diesel cars' operating cost savings would pay back the higher vehicle purchase price was dependent on when the diesel vehicle was purchased, relative fuel prices, the number of miles driven per year, the make and model purchased, the purchase price, and financing.

It was shown in further analysis that diesel car owners' satisfaction with their diesel vehicle and the likeliness they would buy another were correlated with their assessment of relative per gallon fuel *prices*. It did not appear they used economically rational analyses of vehicle and fuel *costs*. That is, diesel car owners appear to have used pump prices as an *indicator* of savings instead of calculating actual net savings (or net costs).

These results are germane to the current case of regulating GHG emissions for several reasons. First, the rise of diesel car sales in the US during the late 1970s and early 1980s appears to have been driven almost solely by a desire for reduced fuel costs (and at least hoped for reductions in maintenance costs). These fuel cost savings were the result of improved fuel economy and for at least some time, lower fuel prices. The combination of these resulted in lower fuel costs. In this diesel case study—in an era of high and uncertain gasoline and diesel fuel prices—some consumers were willing to pay more for a vehicle with better fuel economy than a comparably equipped gasoline vehicle.

However, the case study also highlights the difficulty of abstracting from historical examples. While it is true that diesel vehicles achieved higher fuel economy ratings, they did so by employing a fuel other than gasoline. This introduced the complication of refueling within a relatively less dense network of stations—a source of uncertainty that would not affect buyers of more efficient gasoline vehicles. Further, the diesel vehicles, while appointed with similar amenities, had lower performance in terms of acceleration, were noisier, and had visible, sooty emissions under hard acceleration.

Second, the payback analysis summarized above should not be interpreted as providing the payback periods desired by buyers of Oldsmobile, VW, or Peugeot diesel vehicles in the 1970s and early1980s. The calculations are simply examples of what those payback periods would have been if people made them at different hypothetical interest rates. Still, the approximately 40 percent fuel cost savings provided by the nominally higher fuel economy of the diesel versions and assumed lower fuel prices could have paid back the higher initial purchase price of these two vehicles in about two or three years.[5]

Third, diesel car buyers appeared to use a simple indicator or heuristic to gauge whether or not they were saving money on fuel costs. This indicator was the per gallon fuel price at the pump. Satisfaction with pump prices—not fuel costs—was correlated with satisfaction with their diesel vehicle and the likeliness they would buy another. Taken together, these second and third points indicate that even under conditions of high fuel prices (and uncertain economic and political times)—conditions that make accurate information about vehicle operating costs especially valuable—consumers appear to have used simplified measures. Notably, as we are seeing now in interviews with households nearly twenty years after this diesel car case study, satisfaction—or more to the point, dissatisfaction with fuel cost—is determined by pump prices for fuel, less so by the fuel economy rating of the vehicle.

Fourth, the extremely wide variation in consumers' implicit discount rates for fuel savings can be interpreted in several ways. If we believed households actually understood these financial calculations, the range could represent a segmentation of beliefs across the population about the time value of money (something that almost certainly exists in some form). Alternatively, if people don't understand these calculations, the range may indicate simple guessing.

3.6.2 More recent US Polling Data on Diesel Vehicles

In 1997 ORCI asked 1,010 adult Americans whether they would buy a diesel vehicle that got 40 percent better fuel economy and cost $1,500 more than a comparable gasoline vehicle. Three-fourths said no, only one-fifth said yes. (Gurikova, 2002. pg. 64). In 1998 ORCI asked the following question about diesel vehicles, "How much would you be willing to pay for a diesel engine that gets 30 mpg compared to the gasoline version that gets 20 mpg?" This study was

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[5] By "nominal fuel economy" we mean that the fuel economy of the diesel-powered models cannot be directly compared to their gasoline-powered variants because of differences in other energy-consuming services, in particular power and torque.

segmented by probable body style of next vehicle to be purchased. The segment with the most interest in this proposed vehicle was the probable pickup truck buyers; probable SUV buyers were also more interested than other body style segments. Across all vehicle types, less than half of respondents said they would buy a diesel engine under the stipulated conditions; *more* than half of probable pickup truck buyers said they would buy a diesel under the stipulated conditions. Across all body styles, 30 percent of respondents said they would pay up to $5,000 dollars; among probably pickup truck buyers, 41 percent said they would pay up to $5,000 for the diesel option.

Figure 8: Willingness to pay extra for a diesel engine that gets 30 miles per gallon over a gasoline engine that gets 20 miles per gallon

Dollar amount	Percent of Total Sample	Percent of probable Pickup Truck Buyers
< or =$500	7	9
$501-1000	8	11
$1001-2000	8	7
$2001-5000	7	14
$>$5000	2	3
none	55	47
don't know	12	10

Source: Gurikova (2002). Table 4.3.4.

A third set of poll data from ORCI in 2001 (Gurikova, 2001, Table 4.3.5) posed the following question:

> "Assume that a new vehicle you want to buy has two engine options that are equally clean, dependable, powerful, odorless, and smooth running. One uses gasoline and the other uses diesel fuel and gets 40 percent more miles per gallon but costs $2,000 more. Which engine option would you buy?"

Similar to the previous question, pickup truck/van and SUV buyers were more likely to be interested in the diesel option. Across all body styles, 27 percent of respondents indicated they would buy the diesel option (under the stipulated conditions). Among pickup truck/van and SUV buyers the proportions were 34 percent and 37 percent respectively. These are three of the body styles for which diesel engines are currently optional. (A small number of compact, mid-size, and luxury sedans from European manufacturers are available in the US.) People familiar with diesel engines would perceive that the question as asked by ORCI offers diesel engines that are more favorable than those engines in the real world, i.e., odorless, smooth running, and a 40 percent efficiency boost. Those who rejected the diesel option either did not judge the benefits to be worth the higher price, or were unable or unwilling to accept the premise of the question, i.e., that diesel engines would be equally clean, dependable, powerful, odorless, and smooth running as gasoline engines.

3.6.3 Recent European experience with light-duty diesel vehicles

More recently Verboven (1999) has tested the assumption of implicit discount rates against diesel and gasoline vehicle markets in Europe—diesel vehicles get better fuel economy than gasoline vehicles but cost a bit more to buy. He finds a range of more reasonable implicit discount rates in his aggregate data, closer to real interest rates.

Still, Verboven *infers* these implicit discount rates and payback periods; he does not directly observe consumer decisions. He believes that in Europe, diesels have reached technical parity with gasoline vehicles, that uncertainty has been removed in the fuel market, and that consumers have good information about their engine options. European policy makers have in recent years used taxes to make diesel vehicles more attractive. Tax breaks and near-technical parity between gasoline and diesel engines (in terms of European emissions regulations) has resulted in increasing sales of diesels. In the first half of 2002, nearly 2 out of 5 new light-duty vehicles sold in Europe had a diesel engine. There is considerable variation across countries. In Sweden, only 6.7 percent of new light duty vehicle sales in the first half of 2002 had diesel engines; more than half those sold in Spain, France, Luxembourg, Belgium, and Austria had diesel engines.

3.7 The Case of Hybrids

Vehicles with hybrid gasoline-electric drive trains have been introduced to consumers in recent years. To date, all such vehicles have been small sedans or coupes, though automakers have promised to release a variety of compact and mid-size SUVs and full-size pickup trucks starting in the summer and fall of 2004. So far, these hybrid vehicles have been sold at a price of a few thousand dollars more than the price of a variety of comparably sized gasoline vehicles. The hybrid models are offered with several optional amenities, e.g., leather seats, multi-disc CD players, and GPS navigation systems, as well as services, e.g. roadside assistance, similar to those offered as standard on the top end of conventional models. Response to the hybrid vehicles has been good, with sales above manufacturers expectations and even manufacturing capacity. And as we have discussed above, Toyota, Honda, and Ford are trying to capitalize on the early popularity of hybrids, competing to identify the environmental benefits of hybrid vehicles with their own brand.

Anecdotal information indicates that used hybrids are currently commanding high prices in the used car market, and that relatively few are traded-in to dealers. Instead, most appear to be sold privately by the original owners and their family, friends, and acquaintances. A quick analysis of new and used vehicle prices indicates that used hybrids are also commanding premium prices compared to otherwise similar gasoline vehicles. A prospective vehicle buyer faced with the choice of buying a new or used vehicle will find themselves paying more, proportionally for a used hybrid than for a similar gasoline vehicle. Based on prices obtained from the web site www.edmunds.com, two-year old 2001 Toyota Priuses are selling for over 70 percent of the price of a new 2003 Prius. 2001 Toyota Echos and Corollas are selling for about 50 percent of the price of a new 2003 model.

The case of the introduction of hybrid vehicles suggests there is a market for a vehicle that costs more than a similar conventional vehicle—if that new vehicle facilitates a discrete step up in efficiency. The question is why people will pay this premium—apparently for both new and used hybrid vehicles? Is it due to fuel cost savings, environmental concerns, innovative technology or some mix of the three?

3.7.1 Hybrid vehicle sales and consumer valuation of "fuel efficiency" and "fuel economy"

There have been many studies in the past couple of decades about consumer willingness to pay for new automotive fuels and technologies, e.g., CNG and electric vehicles. Most relevant to our discussion here is the willingness of consumers to pay for hybrid electric vehicles, which offer greater fuel efficiency. Hybrid vehicle sales provide a preview of the issues concerning upscale buyers and willingness to pay for fuel efficiency.

For more environmentally oriented, affluent car and truck buyers, fuel efficiency may be a more desired attribute than fuel economy. More affluent buyers may be, or become, motivated if the technology used to accomplish higher efficiency is interesting or tied to social benefits like reduced greenhouse gas emissions and fuel security. In this instance, fuel economy, i.e., saving money, is a secondary benefit rather than the primary benefit.

If consumers were more interested in fuel efficiency than fuel economy, this would diminish and possibly even negate any rebound effect (in which lowering the cost of travel through higher fuel economy results in more travel). One of our interviews with a hybrid buyer revealed that the vehicle prompted searches for additional energy saving and travel reducing—not increasing—behaviors. They have begun to walk to market and are investigating transit schedules for commuting. Consumer interest in fuel efficiency might also counter arguments that the added cost to OEMs of new fuel economy technology will slow the overall turnover in the fleet, resulting in older vehicles being used longer, thus slowing improvements overall. In the case of reduced fleet turnover, it might be that consumers pick better efficiency, not for the few dollars it saves but in the same way they pick other added values.

3.8 Payback period / discount rates

Recent studies, especially those of automotive companies, have claimed that car and truck buyers will, on average, want to get back any increased purchase price due to new, improved fuel economy technology within three years (see Greene, 2003 for an example). The idea behind a payback period is that consumers will respond in a rational way to price increases. Few vehicle attributes are viewed in this way; for example consumers do not expect financial payback on leather seats, acceleration, or safety. (In the case of safety, people arguably are paying more for technologies they hope never payback; it all depends on how they view the probability of being in an accident severe enough that the additional safety technologies make a positive difference in protection and survival.) In the case of fuel economy, the assumption is that the consumer makes a simple calculation to estimate a payback period. For example, the consumer may estimate that a more efficient vehicle will cost $600 more to buy, but that he or she will save $200 per year in fuel, thus get a payback in three years. A more complicated approach uses what is called the *implicit inter-temporal discount rate*. In this case a consumer must make a calculation based upon both the annual fuel cost saving of $200 but also the annual interest value of the money on the $600 depending on the investment opportunities for the consumer. In this hypothetical case, the payback would be longer than three years as future savings are discounted.

While this makes some sense from the standpoint of implicit discount rates assumed by economists in a theory of consumer behavior, the idea that consumers actually use discount rates in making decisions is not accepted outside of economics. (The point is not whether they should, but whether they do.) Even the idea of payback calculations is seldom observed in household decision-making. Consumer researchers, particularly those looking at energy-using appliances, have argued that such interest calculations are beyond most consumer decision capabilities (Stern, 1992), cultural models (Kempton, 1995), and raw ability to calculate (Chater et al, 2003). A wide set of studies in the 1980s and 90s found that consumers were relatively risk averse, inferring consumers had discount rates as high as 70 percent for some energy-intensive appliances such as air conditioners (Sanstad and Howarth 1995). Risk-aversion in this case translates into consumers who prefer to pay less now for a more energy consuming product, than risk not getting back an initial up-front "investment" in a less energy consuming product. Such aversion is consistent with steeply discounted future savings.

Within the economics literature, various analyses in the 1980s concluded that consumers use implicit interest rates ranging from 4 to 40 percent in valuing energy savings associated with automobile purchases (Train, 1985; Greene, 1983). In Calfee's (1985) analysis of hypothetical choices of electric vehicles he calculated implicit discount rates for future fuel cost savings ranging from essentially zero to 92 percent. The evidence also suggests discount rates vary with income; on average higher income households appear to use lower discount rates than do lower income households. This is the equivalent of saying that, all else equal, higher income households should be willing to wait longer for a given investment in improved fuel economy to be paid back.

3.8.1 Use of Payback as an Explicit Policy Tool: Case of CNG in New Zealand[6]

There is at least one example of a case where payback period has demonstrably been important to consumers' decisions whether to adopt a comparatively expensive automotive technology. As a pre-condition of qualifying for a government-subsidized loan to pay for the cost of converting a light-duty vehicle to dual-fuel gasoline-natural gas (or gasoline-propane) applicants in New Zealand had to demonstrate a payback period of 24 months or less. Government-subsidized loans were available from 1983 to 1987. In 1985, terms of these loans were made less favorable; down payments were required, interest rates were increased, and the total number of available loans was limited.

The consumer experience in New Zealand involved a visit with a loan officer to make the simple payback period calculation. It is not surprising then that Kurani's (1992) analysis showed that payback period was an important part of consumer decision-making regarding vehicle conversions. It is equally clear that a 24-month payback period was not a result of consumer decision-making, but a cause of decision-making imposed by policy. In fact, as with buyers of light-duty diesel vehicles in California during the late 1970s and early 1980s, Kurani found that buyers of CNG (and LPG) conversions in New Zealand used unit fuel prices as measures of their satisfaction with their choice. The following discussion is excerpted from Kurani (1992).

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[6] This section is based on a case study of dual fuel light-duty vehicles in New Zealand conducted by Kurani. We include here updated discussions. The original study is detailed in Kurani (1992).

> Only the simple cost indicator, fuel price, corresponds to changes in kit sales. But recall that a person deciding whether to convert a vehicle in 1985 doesn't know that the fuel price advantage of new fuels is going to continue to decline. What she knows is that after five years of an increasing fuel price advantage for CNG, there has now been a one-year decline. What is the only possible assumption about future fuel prices? Only this, that they are uncertain—more so because the government has stepped back from strong statements in favor of maintaining the fuel price advantage and has begun to discuss deregulating the price of gasoline. (In the case of payback calculations I have implicitly assumed no relative change in fuel prices over time. This is the simplest assumption and the one used in loan qualification calculations.)

3.8.2 Detailed Household Examinations of Automotive Purchases and Fuel Economy

Early findings from the work we are still conducting indicates that it might be misleading to ask car and truck buyers about payback periods or discount rates. In the 54 detailed interviews we have completed to-date with California households, we have not encountered a single household or individual who have employed "payback period" concepts in their decisions about automobile purchases–either used or new. When questioned about payback periods, only a few understand the idea in the context of a car purchase, especially the idea of a payback period for fuel efficiency technology. Those who fully grasp payback periods or discount rates are those employed in financial careers, engineers, and others who are accustomed to making calculations.

Many aspects of vehicle purchases are not amenable to "payback" concepts—consumers might think leather seats increase the resale value, but don't expect to be "paid back" for their aesthetic appeal. Perhaps the one area in which payback concepts are used by several of our respondents is reliability of the vehicle, and therefore costs of maintenance. Here we do encounter some sensibilities by consumers about payback, but not in terms of calculating a specific payback period. Consumers are more concerned with identifying a reliable brand of car, than in calculating payback periods on hoped for reductions in maintenance and repair costs.

When pressed to state a payback period related to higher fuel economy, many households have been unable to estimate or even imagine one. Most commented that they had never thought about payback periods, and imagined that they would have to "do some math." One financial analyst responded to our questions about the possible role of fuel savings in his household's vehicle purchases, saying, "Oh, you mean the payback period. I never thought about it that way."

What is clear is that no household, not even those who understand the calculations to find a payback period, ever actually made such calculations including fuel costs for their automotive purchases. If they do offer a payback period, they arrive at a number in one of a number of ways, including the following:

1. The length of time they financed a recent vehicle (typically three to five years)
2. The length of a lease of a current vehicle (often five years)
3. The length of ownership of a vehicle (depends on household and vehicle)
4. Some are optimistic, imagining they spend much more on fuel per year than they really spend and that paybacks are possible within one or two years.

None mention discount rates for future fuel savings.

4 Conclusions

We believe the meanings of important terms like “fuel economy” and “fuel efficiency” are 1) not shared by energy experts and lay consumers, and 2) may be evolving from their current meanings. The term *fuel economy*, while defined in federal law as “miles per gallon” (under specified test conditions), has historical usages linked to saving both fuel and money. In addition to these historical, political, and marketing meanings, experts and lay people distinguish “fuel economy” from “fuel efficiency” differently.

Energy and engineering experts tend to narrow the definition of *fuel efficiency* to its strictest technical measure—the ratio of useful energy out of an engine’s driveshaft to a unit of input energy. With this definition of efficiency, things like increases in fuel economy, size, weight, luxury amenities, towing, four-wheel drive, and more are all services that can flow from increases in efficiency.

Most consumers we have interviewed say fuel economy and fuel efficiency mean the same thing to them. If pressed for a distinction, many will say fuel economy is about money, and fuel efficiency is about how much gasoline is used. One respondent stated that fuel efficiency is a “classier” way to say fuel economy. A few respondents associate fuel efficiency with the new hybrid electric vehicles from Toyota or Honda. These respondents may characterize efficiency in terms of “saving natural resources,” but none mention greenhouse gas or CO_2 reductions or climate change in general.

It seems clear to us from even a limited number of interviews that it is unlikely consumers in general make the distinction between fuel efficiency and fuel economy that experts do. The implications for this lack of shared understanding include the possibility of mistaken inferences and conclusions from surveys and other research on consumers.

We may be moving from a past in which fuel economy was a primary component of a cost axis in the automobile market to a future in which fuel efficiency is a primary component of a value axis. Fuel economy is linked to a past in which many Americans had to budget their use of gasoline and fuel economy was associated primarily with reducing vehicle size, weight, and power; vehicle economy stood in contrast to luxury and power. To many consumers, fuel economy carries the notion of cheap vehicle. Along side this notion of economy, federal fuel economy provisions such as Corporate Average Fuel Economy standards were shaped by national security concerns stemming from the 1970s and 1980s oil costs and growing imports. But with the low real price of gasoline in the past couple of decades compared to the escalating cost of other aspects of vehicle ownership—e.g., purchase price, financing, and insurance—fuel economy has been shrinking in importance in the vehicle market. Despite minor ups and downs in gasoline prices in the last few years, almost all growth in the automobile market has been towards larger, more powerful, and less economical vehicles. The economy segment of the market shrinks along with profits from that segment.

In effect, over the past several decades, consumers have complained about gasoline prices as if they see (which in fact they do) the current prices shown in Figure 1. However, they have made vehicle purchases (and other fuel-use determining decisions) as if the impact of the unit price of gasoline on them is shown by the constant dollar price curve. Current prices are cause for complaint, but over the longer term the generally declining generalized unit cost of gasoline has facilitated more energy consuming behavior.

The existing econometric literature offers little insight into this specific issue or to the central questions posed for this review—how will consumers respond to more economical vehicles that cost more to buy than less economical, but otherwise comparable, vehicles? Much of the literature is from a time when such choices simply were not available to consumers—thus there is no revealed data to analyze. Literature on revealed and stated choices for alternative fuel and electric vehicles does address the question of whether people will pay more for vehicles with lower operating costs, but in these analyses any changes in operating costs are confounded with changes in fuel type and therefore price, as well as fuel availability and refueling location. The most nearly relevant literature is on household response to higher gasoline prices. This literature indicates that household travel is relatively unchanging in the face of increases in gasoline prices in the short term; that households can make counter-productive changes, e.g., reducing miles of travel but shifting remaining travel to less efficient vehicles.

Additionally, there is the more specific question of how consumers have responded to regulation induce costs, such as air bags or catalytic converters. As we note in the review, consumer response these regulated costs are probably not discernable because they are not advertised to buyers and are buried among bigger price increases overall in the market in the past three decades as buyers have shifted to SUVs and other higher priced vehicles packages.

There may be lessons from past experiences with alternative fuels. The rise of diesel car sales in the US during the late 1970s and early 1980s appears to have been driven almost solely by a desire for reduced fuel costs (and at least hoped for reductions in maintenance costs). These fuel cost savings were the result of improved fuel economy and for at least some time, lower fuel prices. The combination of these resulted in lower fuel costs. In this diesel case study—in an era of high and uncertain gasoline and diesel fuel prices—some consumers were willing to pay more for a vehicle with better fuel economy than a comparably equipped gasoline vehicle.

However, the case study also highlights the difficulty of abstracting from historical examples. While it is true that diesel vehicles had higher fuel economy, they did so by using a fuel other than gasoline. This introduced the complication of refueling within a relatively less dense network of stations—a source of uncertainty that would not affect buyers of more efficient gasoline vehicles. Further, the diesel vehicles, while appointed with similar amenities, had lower performance in terms of acceleration, were noisier, and had visible, sooty emissions under hard acceleration. These differences though all point to people paying a higher generalized cost—in terms of money, performance, and convenience—than strictly the upfront monetary cost, for fuel cost savings (and perhaps longer driving range per tank-full). They did so however in an era of not merely increasing fuel prices, but actual gasoline supply disruptions.

From both the case of diesel cars in California and CNG vehicle conversions in New Zealand we learn that buyers appeared to use a simple indicator or heuristic to gauge whether or not they were saving money on fuel costs. This indicator was the unit fuel price at the pump. Satisfaction with unit pump prices—not fuel costs—was correlated with satisfaction with their diesel vehicle or CNG conversion and the likeliness they would buy another. Even under conditions of high fuel prices (and uncertain economic and political times)—conditions that make accurate information about vehicle operating costs especially valuable—consumers appear to have used simplified measures. Notably, as we are still seeing now in interviews with households, satisfaction—or more to the point, dissatisfaction with fuel cost—is determined far more by pump prices for fuel, and less so by the fuel economy rating of the vehicle.

But as fuel economy has lost much of its market value, fuel efficiency, advanced technologies, and environmental values are an emerging value axis for consumers. Advanced technologies, such as hybrid vehicle systems, promise improved fuel economy without sacrificing luxury, size, weight, and power. And such new technologies offer cleaner air and reduced CO_2 emissions. Consumers are in a period of transition in technology, knowledge, and values.

The current introduction of hybrid vehicles in some ways expands on earlier episodes when consumers were offered non-incremental improvements in fuel economy. Based on historical data reviewed in Section 3 on average household expenditures for new vehicles, we find little reason to believe that in any aggregate sense safety and emissions regulations have stymied new car sales because of associated price increases. By the mid-1990s households were spending less of their income, in the aggregate, for new cars than they had in the late 1970s. It appears as if no more than one-third of the increase in average expenditure for a new car is associated with regulated safety and emissions improvements. The choices of some consumers to spend several hundred more dollars to buy diesel passenger cars also shows a willingness to make non-incremental changes under specific conditions.

It should not be inferred that “regulated” is synonymous with “not desired by consumers.” The question comes back to market segmentation and the ability to craft regulatory language that facilitates and makes the most of differences in consumer willingness to pay. Such segmentation is not based on inherent and unchanging preferences. The relevance of GHG reductions is subject to change based on information, education, culture, and opportunity.

We are interpreting our initial findings from our household interviews to mean that payback periods are probably a misleading concept as they have been applied in previous surveys. Minimally, surveys should establish first whether or not a consumer has ever employed a payback concept in a vehicle purchase, and whether the consumer would consider it applicable or practical for them to consider payback calculations related to fuel efficiency technologies. Consumers could be educated about payback periods. We are hypothesizing that some households might be convinced to accept longer payback periods given the social value of fuel efficiency combined with the savings from fuel economy; however others may require shorter payback periods if they see the declining role of fuel costs in their overall cost of vehicle ownership.

This review points to two diverging viewpoints. On the one hand, if consumers were to think in terms of pay back periods (and the related, more sophisticated, metric of net present value) then averages such as the “three year” figure cited by way of example by Greene (2002) could be meaningfully interpreted (though knowing the distribution of payback periods would be more useful). Almost every study conducted of consumer payback periods related to energy conservation shows a wide variety of *implied* discount rates. (That is, these studies don’t directly examine individual household expenditures, but infer discount rates from statistical models based on the assumption that the rate exists in the first place.) Never the less, a distribution of rates across households would suggest the existence of a market that can be segmented according to how long people are willing to wait to be paid back. We should not be concerned initially with the "average" payback period, but with those people who are willing to wait longer. Still, even within a context where payback period calculations were imposed on consumers, those signals carried far more than price information. In the case of dual-fuel vehicles in New Zealand, payback periods—as an explicit element of government policy—came also to signify government commitment to alternative fuels. The payback calculation and government loans were part of a package of price supports and taxes, refueling station incentives, and other government support for alternative fuels. Across the board retrenchment on all these programs created uncertainty that may have had more to do with the continued decline and eventual end of New Zealand's experiment with natural gas as a transportation fuel than did the actual effect on vehicle conversion and fuel prices.

On the other hand, few analysts outside economic traditions accept the plausibility of consumer calculation of payback periods. Our ongoing work to study household automotive purchases supports this contention. We have found no household that thinks about fuel economy in terms of payback period. When asked to do so, households are clearly unfamiliar and uneasy with the concept. They grasp for familiar temporal anchors, e.g., their finance period, how long they expect to own the vehicle that are irrelevant to structured payback period calculations. Under these conditions, it is vital to pose questions about payback periods to households in an interactive context that allows the researcher to assess the "quality" of the response. Did the respondent understand the question? Have they ever actually thought about it before? Are they constructing an answer to a novel question on the spot or are they referring to a mental library to retrieve an answer from a question they have previously answered for themselves? In this view, the wide variation in consumers' implicit discount rates for fuel savings may indicate differences in understanding the question (of valuing energy savings over time) and its associated concepts, different heuristic answers, e.g., the temporal anchors of finance periods and expected time of ownership, and simple guessing.

To return to one of our basic questions—will consumers pay more for a more fuel economical vehicle? —We see indications they will under conditions of rising fuel prices, fuel scarcity, and vehicle-fuel options that appear to offer non-marginal options. Higher fuel prices alone—at least those experienced over the past few years—do not appear to prompt the purchase of vehicles with higher fuel economy ratings. More telling though, we find little evidence that consumers have the basic tools to construct meaningful answers to questions that have been posed to them about this issue. Our in-depth—and admittedly still preliminary work—research with households indicates the following.

> First, assistance with payback or net present value calculations may simply reveal to most households that they will save less money, or wait longer to be paid back, than they guess.
>
> Second, estimates of consumers' purported payback periods for fuel cost savings are likely too deeply flawed to form the basis of any policy. Many studies draw inferences based on the assumption that consumers act, or will act, *as if* they make decisions based on payback concepts. It is important to penetrate this assumption to understand how consumers actually make decisions.
>
> Third, new—non-marginal—options matter. We see evidence that hybrid electric vehicles—which offer a non-marginal improvement in fuel efficiency and fuel

economy—are subtly re-defining concepts like “fuel efficiency” to incorporate images of advance engineering and high quality.

Four, differences between expert and lay understandings of the basic terminology of the debate must be made clear and incorporated into future research. The possible cost of continued mis-communication includes mistaken inferences and therefore mis-designed policies to reduce greenhouse gas emissions and the risk poorer air quality.

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6 Appendix A

This Appendix summarizes polling data relevant to the underlying goal of reducing greenhouse gas emissions from the transportation sector. It includes primarily citizen response to political polls, as opposed to consumer responses to new products and technologies.

6.1 Consumers and the larger context of collective benefits of reduced greenhouse gas emissions

Government policy is one mechanism through which collective decisions are enacted in democratic societies. Regardless of their level of factual knowledge, citizens of those societies are asked repeatedly for their opinions of various policy measures. And more recently, as efforts to implement “market based solutions” to a number of social problems have been promoted, people are being asked to act as consumers, again regardless of their level of knowledge.

6.1.1 Understanding polling data on consumers, climate change, and fuel efficiency

We will interpret polling data and other studies of how people respond to specific strategies to reduce CO_2 emissions. These strategies include, but are not limited to, what it appears people will pay for reductions in greenhouse gas emissions from their personal travel. Rarely is the question asked as such. Much more commonly, and therefore a much greater part of this review, questions have been asked about greenhouse gas reduction strategies such as increasing fuel economy and switching to lower carbon fuels. We note that results of public polling in this topic area (as is true of all polling) are subject to large contextual effects. In fact, the very incidence of relevant polling tends to be driven by related policy events rather than an ongoing effort to monitor citizen/consumers. For example, numerous polls were undertaken leading up to the climate negotiations in Kyoto in 1997. Another round of polls accompanied the Bush administration’s announcement in the spring of 2001 that the US would not ratify the Kyoto Treaty on climate change. Conversely, Wirthlin Worldwide dropped a line of questioning on the public’s perception of the environment in the fall of 2001. Wirthlin had established a more than decade-long series of data, but in response to the terrorist attacks on September 11, 2001 they dropped these questions from what would have been their expected spot in a national survey done in early October of that year. (As we will discuss, the question was asked in a CBS/New York Times poll in the fall of 2002.)

Several events may have changed the context in which people evaluate the potential threats of global climate change, greenhouse gas emissions, and strategies to reduce them. The election of George W. Bush may have marked change in Americans’ assessment of environmental threats and their solutions. The terrorist attacks on the U.S. on September 11, 2001 may have done the same. The recent event with arguably the most direct effect on Americans and their vehicle purchase and use behavior was the initiation of a war in Iraq during the spring of 2003. The war created at least short-term uncertainty about petroleum prices and supplies. It also created clashing images of war protesters demanding (among other things) an end to what they claimed was a “war for oil” and war supporters and Hummer H2 drivers proudly identifying with real-time images from the war showing the military-version Humvee in action.[7] In California, it is also possible that the political battle over the passage of AB 1493 during 2003 permeated public discourse to the extent that that discourse itself has shaped citizen/consumer awareness, knowledge, and consideration of global climate change and its possible solutions.

Before we examine citizen/consumer response to specific policy strategies and market conditions, we examine the larger policy context. Before addressing whether consumers will pay more for products that reduce greenhouse gas emissions from transportation, we address whether citizens support the larger policy context in which governments propose to do “something” about greenhouse gas emissions. Polls driven by events such as those mentioned in the previous paragraph are typically designed to provide specific input to support arguments in favor of, or in opposition to, some outcome of the events. It is especially important to deconstruct such polls—to understand the sample, to have access to the full questions, to be able to compare question wording to other polls.

Another shortcoming of event-driven and policy-driven polling is that long-term, consistent sets of questions, asked of either a repeated cross-section sample or a panel, rarely exist. We show such long-term data series where we are able. As we have before, we recommend a multi-sponsor project to design and conduct a long-term tracking study to assess in a consistent manner over time citizen/consumer awareness, knowledge, and consideration of issues related to fuel economy, climate change, and clean air. Finally, studies and polls are infrequently conducted for California alone. Much of the data we present is drawn from national studies; we present studies and data specific to California on topics for which we have discovered them.

Efforts to shape public behavior through information campaigns and even marketing, are predicated on the idea that if people correctly understand a problem, and are offered a means to solve that problem, they will chose to adopt the solution rather than perpetuate behaviors that cause the problem. This premise shapes our analysis of political behaviors such as voting and participating in public meetings and consumption decisions about where to live and what products to buy. It also shapes responses to polls. Questions such as those that ask people whether they are willing to support tax increases to solve a particular problem can confound the problem with the solution—especially if the problem is not well understood by the respondent. That is, people may respond to the notion of higher taxes separate from their assessment of the problem simply because they don’t understand the problem well enough to have formed an assessment. The pollster thinks the respondent is addressing the problem/solution combination, while the respondent is communicating only their opinion of the proposed solution.

6.1.2 What do consumer/citizens Know? What do they support?

So what do Americans know about environmental issues, and in particular, those related to global climate change? The results from three studies over the period from 1997 to August 2002 suggest that Americans lack basic knowledge about the environment to make informed choices about proposed solutions to a host of problems.

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[7] For reporting on the impressions of some Hummer H2 drivers, see for example Hakim, D. (2003a).

The National Environmental Education and Training Foundation commissions the survey firm Roper Starch Worldwide to conduct a *NEETF/Roper National Report Card on Environmental Attitudes, Knowledge, and Behaviors in America*. In 1997, the survey included a battery of 12 factual questions; the 1501 adult (age 18 or older) American respondents were graded according to how many they could correctly answer. The same battery of questions was repeated to a sample of 1505 adult Americans in the year 2000 study.[8] The headline of the press release announcing the 1997 results was titled "Two out of Three Adults Flunk Simple Test on Environmental Knowledge." Following the 2000 survey, the conclusion was that two out of three adults *still* flunk the same test. The NEETF's gave the following general assessment in the second study:

> "…Americans lack the basic knowledge and are unprepared to respond to the major environmental challenges we face in the 21st century."

In 2002, NEETF and Roper ASW concentrated on energy topics in their 10th Annual National Report Card.[9] As with previous studies, NEETF reports that Americans know little about their energy, and worryingly, know less than they think they do. Only 12 percent of the sample earned a passing grade on the energy-specific environmental test; approximately three-fourths say they have "a lot" or "a fair amount" of knowledge of energy.

On the topic of the fuel economy of the cars and trucks they drive, most Americans think automotive fuel economy is getting higher. Only 17 percent of respondents knew (or guessed) that on-road measures of miles per gallon declined over the past several years. Only one-third knew that transportation is the largest user of petroleum in this country. On questions related to energy production and global warming, Americans were also uninformed. Just as many Americans mistakenly believed that most of our electricity comes from hydroelectric projects as correctly knew that most of our electricity comes from burning coal, oil, and natural gas.

6.2 General Public Support for Environmental Policy

We see two phenomena in polling data that are of interest to this review. First, there are efforts to characterize people as either more or less in favor of action by government to achieve environmental goals. Second, there are efforts to shape the answers to these questions by manipulating the context in which the questions are answered. These efforts to lead respondents may use question wording, question order, or some other element of the survey instrument.

We raise these issues to highlight the fact that the only survey results we have found in which high percentages of respondents have opposed government policy to address greenhouse gas emissions or strategic policies to achieve GHG emission reductions are studies in which

[8] According to information on NEETF's web site (http://www.neetf.org/roper/roper.shtm), the series was initiated by the Times Mirror Magazines in 1992 in collaboration with Roper Starch. The NEETF took over the survey in 1995. NEETF represents that their survey provides "…the only longitudinal data available on what Americans know and think about important environmental issues."

[9] Roper also conducted this survey. Again, the sample was adult (age 18 or older) Americans contacted by telephone. The sample size was 1503. The study was conducted in August and September 2001. Though specific dates are not provided in the summary available to us, we surmise the study was completed prior to the terrorist attacks of September 11, 2001.

respondents were clearly lead to oppose such actions. Examples include a poll by Wirthlin (2001) and a Competitive Enterprise Institute report on CAFE and safety (2002)[10].

Most studies conducted over the past few years reveal that most Americans—in spite of or because of their relative ignorance of energy and environmental issues—support further efforts by government to solve environmental problems; differences do exist in levels of support across different, more specific, environmental problems. In the series of NEETF/Roper studies cited in the previous section, a plurality of Americans consistently believes regulations have "not gone far enough" to address environmental problems and issues. Even in 2001, after the current Bush administration came to power, a plurality of respondents (44 percent) to the NEETF/Roper poll said regulation had "not gone far enough." This was more than double the percentage of those who thought that "current regulations go too far" (21 percent). Most of the remaining believed the then current laws "struck about the right balance."

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[10] In the aftermath of the terrorist attacks of September 11, 2001, Wirthlin Worldwide constructed a series of questions in which respondent's that chose to object to drilling the Arctic National Wildlife Reserve had to identify themselves as environmentalists in league with Saddam Hussein. The questions and responses are as follows:

"As you may or may not know, the U.S. Congress is presently debating whether or not to allow oil and natural gas production in the Arctic National Wildlife Refuge in Alaska, also know as ANWR. I am going to read you some statements regarding the ANWR. After I read each one, please tell me if you agree or disagree with each statement."

Increasing our dependence on foreign oil will make the "Saddam Husseins" of the world more powerful and America more vulnerable.	
70 percent	Total Agree
50	Strongly Agree
19	Somewhat Agree
29	Total Disagree
14	Somewhat Disagree
15	Strongly Disagree
1	Don't Know/Refused
Environmentalists say we should preserve America's last pristine wilderness in Alaska even if it limits our national security.	
34 percent	Total Agree
16	Strongly Agree
18	Somewhat Agree
64	Total Disagree
28	Somewhat Disagree
36	Strongly Disagree
1	Don't Know/Refused

The Competitive Enterprise Institute (2002) constructs a series of questions in which support for CAFE standards erodes as they "explain" its adverse effects on safety. Nowhere do they acknowledge the uncertainty and disagreement among experts about the information presented to respondents.

For many of the past years, Wirthlin Worldwide has asked the following question of adult Americans:

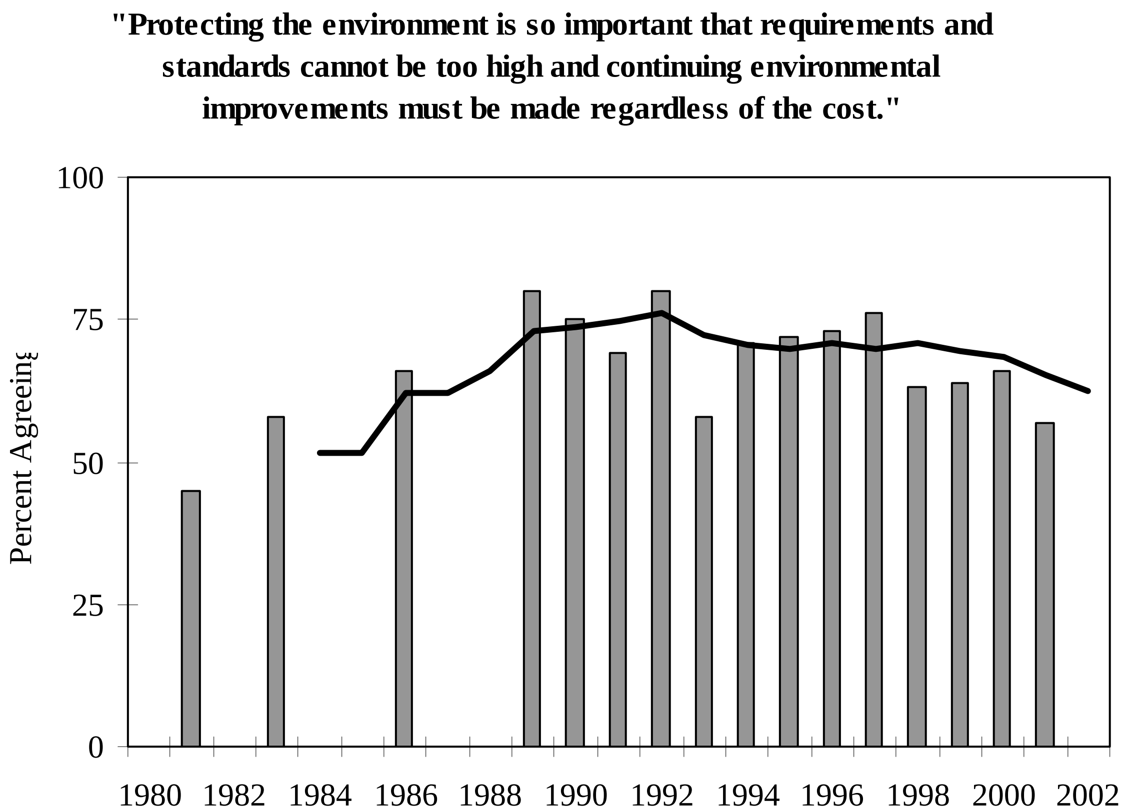
> "Do you agree or disagree with the following statement? Protecting the environment is so important that requirements and standards cannot be too high, and continuing environmental improvements must be made regardless of cost."

Though the allowed answers are a four-point scale from "strongly agree" to "strongly disagree," Wirthlin Worldwide typically reports the data only as "agree" or "disagree." (The question responses do allow for "don't know," but there is no mid-point to the response scale indicating a neutral response.) Wirthlin Worldwide dropped this question from their immediate post-September 11, 2001 poll (in order to focus on America's response to the attacks). The question was included in a CBS News/New York Times Poll conducted in late-November, 2002.[11]

For the past two decades a majority of Americans have claimed to be willing to pay very high costs to improve environmental quality. And even if there was a decline from the last year of the Clinton administration to the second year of George W. Bush's administration, still a majority of Americans agreed with this statement.

[11] In general, this question has been asked in a telephone survey. The samples in most years have been made up of about 1,000 adult Americans.

Figure A1: Importance of protecting environment



Note: The trend line is a five-year moving average.
Sources: 1981 to 2000: Wirthlin Worldwide, 2000
2002: CBS News/New York Times Poll, November 2002

Another question in the same CBS News/New York Times poll directly poses the question of whether respondents believe government—and the Bush administration in particular—should be doing more or less to protect the environment. The question and responses are summarized in the following table.

Figure A2: CBS News/New York Times poll "When it comes to regulating the environment and safety practices of business, do you think the federal government is doing enough, should it do more, or should it do less?"

Percent	All	Republicans	Democrats	Independents
"Should do more"	62	46	72	67
"Doing enough"	25	38	20	21
"Should do less"	7	12	4	6
"Don't know"	6	4	4	6

Note: The CBS News/New York Times poll was conducted between November 20 and 24, 2002. The sample was a national sample of 996 adults. Sampling error is reported to be ± 3 percentage points.

The role of government in protecting the environment is one specific question that follows from the more general relationship between business and government in the area of environmental protection. The following question asks for the respondents' opinions of whether or not business can be trusted to "take care of the nation's resources," or whether "strong government rules and regulations" are required to protect the environment from businesses. In this case, there is more clear-cut evidence that Americans in general and Californians in particular believe that strong environmental regulations and enforcement are required to protect the environment. The margin of those who believe in the need for environmental regulation to those who believe businesses can be trusted is almost two-to one in California, and is more than that nationally.

Figure A3: LA Times Poll on business and environmental stewardship

Which of the following statements comes closer to your view: "Many businesses can be trusted to take good care of the nation's natural resources, and the government should intervene only in the worst cases," or "Many businesses will cut corners and damage the environment unless strong government rules and regulations are in place"?		
Percent	National	California
Businesses can be trusted	27	33
Businesses will cut corners	65	63
Don't know	8	4

Source: Los Angeles Times (2001)

6.2.1 Can we say anything more specific about Californian's perceptions of the role of government in environmental issues?

As describe in the preceding paragraphs, some survey questions asked specifically of Californians support the conclusion that Californians continue to support a strong role for government—federal, state, and local—in promulgating and enforcing stricter environmental laws. Studies done by the Public Policy Institute of California (PPIC) probes this in greater detail. The PPIC focused on environmental issues in their June 2000 (Baldassare, 2000) and June 2002 (Baldassare, 2002) Statewide Surveys.

Responses to additional questions lend credence to the interpretation that Californians believe government has a role to play in addressing environmental issues. The proportion of Californians who believe that stricter environmental laws and regulations are worth the cost rose from the survey taken prior to the 2000 general presidential election to the one in June 2002; rising to the point that more than twice as many Californians believe it as believe stricter environmental laws and regulations hurt the economy.

Figure A4: Change in number of Californians wanting more environmental regulations

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right. (1) Stricter environmental laws and regulations are worth the cost; (2) Stricter environmental laws and regulations cost too many jobs and hurt the economy.		
Percent	2000	2002
1) Worth the cost	57	64
2) Hurt the economy	37	31
Don’t know	6	5

Sources: 2000; Baldassare (2000). 2002; Baldassare (2002)

More Californians opposed offshore oil drilling—even if it means higher gasoline prices—in 2002 than did in 2000. The shift is not as dramatic as in the previous question. Still, what was a majority position in 2000 became even stronger by 2002 when nearly six in ten Californians said they were willing to see an (unspecified) increase in gasoline prices rather than see the California coast opened to oil drilling.

Figure A5: Californians and off shore drilling

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right. (1) Policymakers should not allow more oil drilling off the California coast, even if this means higher gas prices for California drivers. (2) Policymakers should allow more oil drilling off the California coast if this means lower gasoline prices for California drivers		
Percent	2000	2002
1) No more drilling	54	59
2) More Drilling	43	36
Don’t know	3	5

Sources: 2000; Baldassare (2000). 2002; Baldassare (2002)

Nearly two-thirds of Californians believe that protecting the environment is more important even if it means restricting energy production, than believe that energy production is more important. Those believing the environment is a higher priority than energy production outnumber those believing energy production is a priority by more than two-to-one.

Figure A6: Californians and energy policy, 2002

Please tell me if the first statement or the second statement in the following questions comes closer to your views—even if neither is exactly right. (1) Protection of the environment should be given priority, even at the risk of limiting the amount of energy supplies—such as oil, gas, and coal—which the U.S. produces. (2) Development of U.S. energy supplies—such as oil, gas, and coal—should be given priority, even if the environment suffers to some extent.	
Percent	Percent
1) Environment is the priority	65
2) Energy is the priority	29
Don’t know/other answer	6

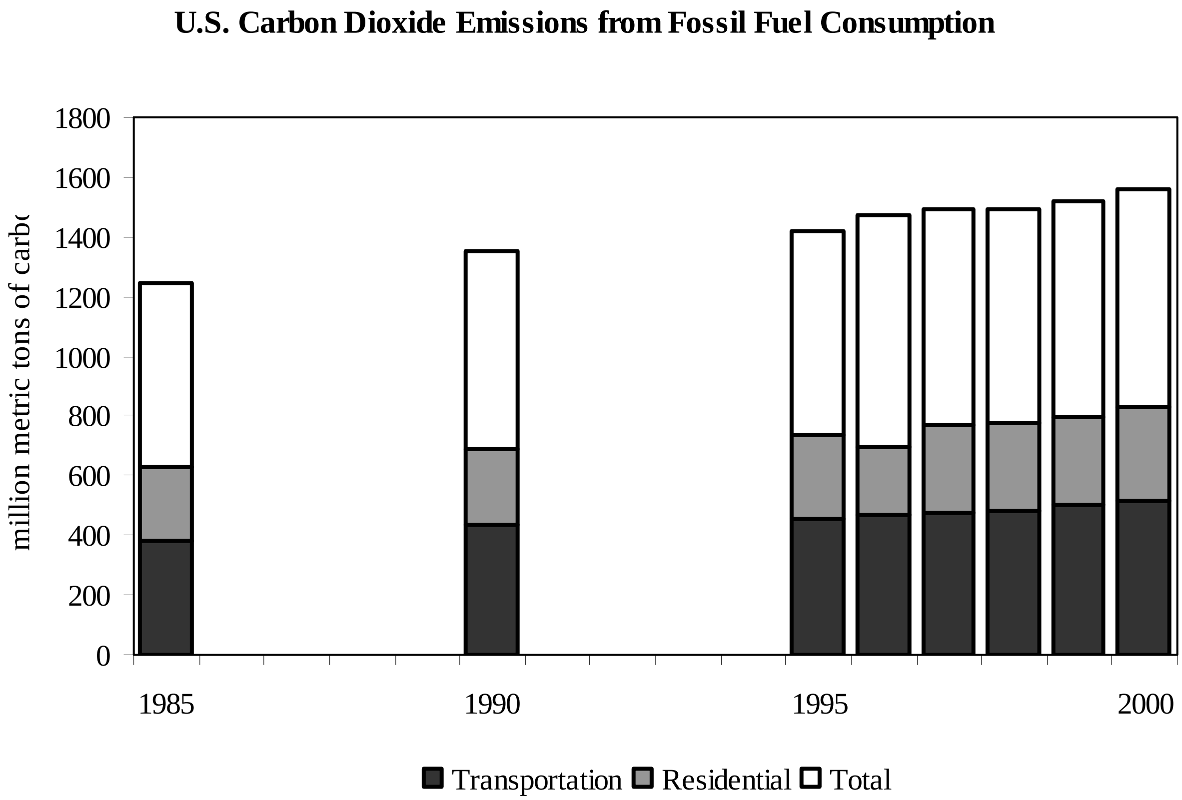
Sources: Baldassare (2002)

6.3 Consumers, Global Warming, and Fuel Economy

6.3.1 Basic Greenhouse Gas and Global Warming Information

There is certain information about global climate change and greenhouse gas emissions that it would be useful if citizen/consumers knew. These include the sources of greenhouse gas emissions and the relative sizes of those sources, the strategies for reducing those sources, the implications of global climate change, and ideally, the private and public costs and benefits of each of those strategies. As some of these (in particular the last) are relatively uncertain even to specialists, we can forgive the lay public for not having a complete picture of how to reduce the risks associated with global climate change. The figure below illustrates CO_2 emissions created by the consumption of fossil fuels in the U.S. over the period from 1985 to 2000. Emissions are divided the transportation sector, the residential sector, and all other sectors. First, are the total emissions for the U.S. large? Using world emissions of carbon as the standard, the answer is yes. In 1990, the U.S. created 23 percent of the world's carbon emissions; this rose to 25 percent in 1999. Within the U.S., how large are the emissions from transportation? They have risen slightly from about 30 percent of the total carbon emissions from fossil fuels in 1980, to about 33 percent in 2000. Further, more CO_2 emissions are created by the use of fossil fuels in the transportation sector than by the use of energy in residences homes.

Figure A7: Global warming and transport sources of CO2



Source: Davis, S.C. and S.W. Diegel (2002), Table 3.4

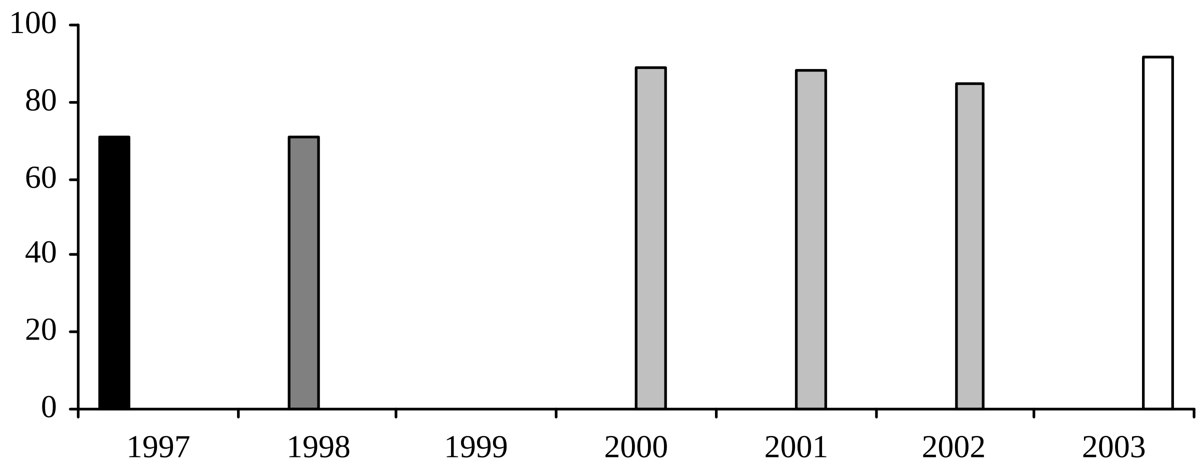
Several studies of citizen/consumer response to global warming are organized around a sequence of questions. The sequence moves from basic awareness of global climate change, through (usually self-reported) measures of knowledge, and on to support for various initiatives to reduce greenhouse gas emissions. As international negotiations of climate change treaties often spark polls of citizens, questions regarding specific international meetings, e.g., Kyoto in 1998 and Bonn in 2001 are often included. We will follow this same general outline in this section.

Data from numerous polls indicate that Americans have heard of the phenomena of global climate change. As the data in the next figure illustrate, by the turn of the 21st century, nine of ten Americans had heard, see, or read about global climate change.

6.3.1.1 Do people think that global climate change is a real problem?

Most Americans and most Californians have heard of global climate change; most believe the problem is real and that something should be done about it. Baldassare (2000) cites original and secondary sources to conclude, “A solid majority (57 percent) of Californians believe that there is evidence to warrant either immediate action (22 percent) or some action (35 percent) to address global warming.” Two years later, he cites responses from a new poll that show the percentage of Californians who believe global climate change is a real problem requiring action increased to 62 percent (Baldassare, 2002). The difference between the years 2000 and 2002 is within the sampling error of both surveys, so any representation of an increase should be made cautiously.

Figure A8: Have people heard of global climate change?



Sources: 1997: World Wildlife Fund National Survey. August 14. Cited in Gurikova (2002).
1998: Program on International Policy Attitudes. October 22-27. Cited in Gurikova (2002).
2000 to 20001: Harris Interactive (2002). Sampling error is reported as ±3 percentage points.
2003: Leiserowitz, A. (2003). Sampling error is reported as ±4 percentage points.

Notably, there are strong differences in responses in the 2002 survey according to political affiliation. A majority of Democrats, independents, and those respondents not registered as members of any political party at least believe there is enough evidence and we need to take some action to address global warming; only amongst registered Republicans do a majority believe either that more research is required before we do anything or that concern about global climate change is unwarranted.

We note that links between fuel economy and global climate change are not solely the purview of radical environmentalists. Two groups have gained national notoriety over the past year—one asking, "What would Jesus drive," and the other linking poor fuel economy to support for terrorism. Even mainstream consumer information sources such as The CarConnection.com have counseled visitors about the link between fuel economy and global climate change. In an online article posted on October 1, 2001 (only weeks after the attacks of September 11) reporter Carol Traeger wrote:

> "If a wallop to your wallet isn't enough to get you to rethink your own family transportation, maybe you should consider the environmental consequences…One of the most important things you can do to reduce your contribution to global warming is to buy a vehicle with higher fuel economy…By cutting back on your fuel usage, not only will you save money and help protect the environment, you'll help reduce our country's dependence on oil imports (a patriotic issue right now) and conserve resources for future

> generations. Plus, you and your kids can enjoy more stops at the yogurt store and fewer stops at the dumb old gas station." (Traeger, 2001).

She goes on to highlight the most efficient vehicle s in a number of vehicle classes and to provide links to government and NGO web sites that have more information. She has woven together several benefits of fuel economy that are in addition to the private fuel costs faced by drivers. This context is largely missing from the economic-based literature, which tends to focus only on what people will pay up front for increased efficiency to save money on fuel costs over time. Those benefits include reducing CO_2 emissions, reducing the nation's dependence on oil (with a specific if oblique reference to Middle East), conserving resources for the future, and the day-to-day convenience of fewer stops at gas stations.

Now, we can take issue with some of these. Within the context of buying a new car, most new cars (with the exceptions of hybrids) have about the same range per thankful—less efficient vehicles tend to have larger tanks. So only by buying a hybrid (at this point in time) can you actually "buy" fewer stops at gas stations. And many economists argue that increases in efficiency aren't the best way to allocate resources, either across contemporaneous uses or across time; they argue for "right pricing." There are notable difficulties with such proposals, not the least of which is their political unpopularity. (See Delucchi, 2000 for a discussion of both theoretical and empirical difficulties of such proposals.)

But the primary difficulty with information such as that presented by Ms. Traeger is the lack of specific follow-up to ascertain the effect of her article. This is not a specific complaint against her or CarConncection.com; the problem is much more general. We know that information linking global climate change to vehicle choices is available from a wide variety of mainstream and not-so-mainstream sources. Rarely however is the provision of information linked specifically to research on the effectiveness of the combined message and media.

6.3.1.2 Policy support in California

We are now poised to ask whether or not there is support amongst Californian's for the state to take action on fuel economy and global climate change. Again, the Public Policy Institute of California has asked this question of Californians (Baldassare, 2002). Their question and the survey responses are reproduced below. A vast majority of Californians supports the state taking action to reduce greenhouse gas emissions from new cars. Even among those who profess to believe that more research is required before taking action a "veto-proof" two-thirds majority favor this action.

These results are repeated in yet another survey by the PPIC in the summer of 2003. A large majority of Californians (68 percent) believes greenhouse gas emissions, if unchecked, will lead to global warming. Even more people (73 percent) state that steps to curb greenhouse gas emissions need to be taken immediately, despite the fact that only a minority (45 percent) believes that global climate change will pose a serious threat to them in their lifetimes. And again, 80 percent of Californians support the state of California taking action to limit greenhouse gas emissions from new cars.

Figure A9: PPIC poll, "Do you favor or oppose a state law requiring all automakers to further reduce the emissions of greenhouse gases from new cars in California by 2009?"

"Do you favor or oppose a state law requiring all automakers to further reduce the emissions of greenhouse gases from new cars in California by 2009?"			
		Belief about Global Warming	
	All adults	Change is real/Action needed	More research needed/Concern is unwarranted
Favor	81%	90%	67%
Oppose	16	9	29
Don't know	3	1	4

Source: Baldassare (2002)

FINAL REPORT

Contract 02-310
Project No. 008545

Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking

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DISCLAIMER

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ABSTRACT

On July 22, 2002, Governor Gray Davis signed AB 1493 into law. This law requires that the California Air Resources Board (CARB) propose rules that would reduce greenhouse gas emissions of light duty vehicles in California. The goal of this study was to provide insight into industry and consumer response to government regulations, especially as they might relate to future regulations that reduce greenhouse gas emissions from vehicles. This report addresses industry and consumer behavior with respect to emissions, safety, and energy use in the U.S. and Europe over the past few decades.

We created and analyzed a large data set of vehicle characteristics, sales, and prices, vehicle financing practices, and exogenous factors such as income, for the period 1975-2003, and supplemented the data analysis with case studies of the introduction of oxidation and three-way catalysts, air bags, and hybrid electric vehicles in the US; and diesel cars in Europe.

We found that costs imposed on vehicles due to US emissions and safety regulations have been significant – somewhere between \$2500 and \$4000 per vehicle. These costs represent up to 1/3 of vehicle price increases since the 1970s. Whether one considers these costs to be large or small, they had little discernible effect on industry performance and activities. The cost increases have been largely accommodated within normal business and market planning processes of companies.

EXECUTIVE SUMMARY

On July 22, 2002, Governor Gray Davis signed AB 1493 into law. This law requires that the California Air Resources Board (CARB) propose rules that would reduce greenhouse gas emissions of light duty vehicles in California. The goal of this study was to provide insight into industry and consumer response to government regulations, especially as they might relate to future regulations that reduce greenhouse gas emissions from vehicles.

The era of vehicle regulation is rather short, but rich in experience. Government regulations in California, US and elsewhere have played a large role in the evolution of vehicle technology and automaker business planning over the past 40 years, and will continue to do so.

This report addresses industry and consumer behavior with respect to emissions, safety, and energy use in the U.S. and Europe over the past few decades. To do so, we created and analyzed a large data set of vehicle characteristics, sales, and prices, vehicle financing practices, and exogenous factors such as income, for the period 1975-2003, and supplemented the data analysis with the following case studies: introduction of oxidation and three-way catalysts, air bags, and hybrid electric vehicles in the US; and diesel cars in Europe.

Emissions regulations have been arguably the most successful. Vehicles are now much lower emitting than several decades ago. Emissions improvement occurred almost exclusively because of persistent and aggressive government regulation. Market factors and consumer behavior played almost no role. These improvements initially were quite expensive, but government persisted because air quality retained strong public support. Eventually, technical innovation resulted in continuing improvements at little or no extra cost. Current vehicles are cleaner burning than ever and yet the cost of emission control per vehicle is less than it was in the early 1980s.

Safety regulation was more complex and protracted. Automakers effectively resisted passive restraints and especially airbags for many years. By the time airbag requirements were adopted in 1991, consumer demand for safety had grown so strong that automakers willingly incorporated airbags well before the imposed deadlines of 1998 for cars and 1999 for light trucks.

Energy regulation has been the most controversial and most complex. The adoption of the Corporate Average Fuel Economy (CAFE) standards in 1975, taking effect in 1978, had a galvanizing effect on the auto industry, with car fuel economy doubling between 1973 and 1985. But fuel prices also soared during this time. CAFE played an important role, but so did fuel prices. Since the late 1980s, car CAFE standards have remained static, and light truck CAFE standards have increased only minimally.

We reviewed one other enlightening experience: the “voluntary” adoption of carbon dioxide (CO_2) emission standards in Europe by automakers. While voluntary, it was made clear that firm enforceable standards would be adopted if the industry failed to attain large CO_2 emission reductions – on the order of 25% per vehicle for the ten year period from when they were adopted in 1998 until 2008. They are nearly on track to do so. The principal strategy has been to switch from gasoline to diesel engines, which have inherently lower fuel consumption, but higher emissions of oxides of nitrogen and particulates. This diesel strategy has been successful, aided by less stringent European Union emission standards for diesel cars and lower diesel fuel and diesel car taxes in most European countries.

The costs imposed on vehicles due to US emissions and safety regulations have been significant – somewhere between $2500 and $4000 per vehicle. These costs represent up to 1/3 of vehicle price increases since the 1970s. Whether one considers these costs to be large or small, they had little discernible effect on industry performance and activities. The cost increases have been largely accommodated within normal business and market planning processes of companies.

We note that industry response to new regulations and new technology is not straightforward, uniform, nor transparent, and that industry behaviors are highly confidential and situation specific. Indeed, many changes in product mix and industry organization have occurred in parallel with the imposition of new government requirements. The market share of light trucks, first minivans and then SUVs, increased dramatically. The industry became much more competitive, with many more large companies from Japan and later Europe gaining considerable market share. And in the past two decades, vehicles have become larger and more powerful. Government regulations clearly played some role in these transitions. The stringent emissions and fuel economy standards in the 1970s gave Japanese automakers the opening to crack the US market, though the rapidly improving and expanding Japanese industry was likely to do so eventually anyway. And the shift to light trucks was encouraged by the less stringent CAFE standards applied to light trucks (and also less stringent safety and emissions standards), providing an incentive to automakers to shift production to minivans and SUVs.

In the end, though, vehicles prices increased much faster over the past decades than did costs associated with regulations, reflecting the considerable improvements in vehicle quality and performance that have taken place over this time. Indeed, we found that even when costly changes were required in a short time – as with the introduction of oxidation and three way catalysts -- the impact on vehicle prices was barely discernible. Vehicle markets have not been perturbed significantly by government regulation in the US, excepting perhaps the perverse effect of CAFE standards encouraging light trucks. In Europe, the situation is somewhat different, but in that case it was a not a single regulatory initiative that led to diesel cars, but rather a cluster of coherent policies and rules.

The minimal disruption caused by government regulations is due in large part to the many advertising, marketing, financing, and pricing tools available to companies. For instance, even with rising prices, automakers have maintained the affordability of vehicles by providing financial incentives and doubling the length of financing periods.

In the short run, automakers can use these tools to adjust to perturbations, whether imposed by government or external market conditions. And in the long term, they respond with technological innovation and product planning changes – building vehicles that last longer, are more reliable, safer, and more environmentally desirable.

The challenge for government regulators as they formulate new regulatory initiatives is to understand shifting market dynamics, anticipate technological innovation, and forecast likely near and long term cost impacts. Easier said than done.

BACKGROUND

On July 22, 2002, Governor Gray Davis signed AB1493 into law. This law requires that the California Air Resources Board (CARB) propose rules that would reduce greenhouse gas emissions of light duty vehicles in California. These rules must be technology based. This study has two goals: 1) provide insight into industry and consumer response to government regulations, especially as they might relate to future regulations that reduce greenhouse gas emissions from vehicles; and 2) provide a modeling tool that CARB can use to investigate customer responses to greenhouse gas vehicle rules in a systematic and rigorous fashion. Two sets of reports are prepared. The second goal is addressed in a report by Dr. David Bunch et al. (2004).

This report is a synthesis of six background reports that address the first goal (Abeles et al, 2004; Burke, 2004; Burke et al, 2004; Chen et al, 2004a; Chen et al, 2004b; and Kurani and Turrentine, 2004a). Together with the background reports, this synthesis report documents regulatory experiences and industry and consumer behavior with respect to emissions, safety, and energy use in the US and Europe over the past few decades. Together, these reports provide insight into how the automotive industry responds to new regulations, how consumers respond to new "green" technology, and the extent to which the cost of compliance is passed through to consumers.

Study Approach

To understand industry response to regulations, we examined historical experiences. We studied relationships between vehicle prices, costs of complying with vehicle regulations, and automotive marketing strategies. We created a large data set of vehicle characteristics, sales, and prices, vehicle financing practices, and exogenous factors such as income, for the period 1975-2003 (Burke et al, 2004). To provide further insight and to control for these external influences, we supplemented the data analysis with more focused studies of cases where government regulations had sharp impacts in a short period of time, or where new vehicle technologies were introduced that significantly reduced greenhouse gas emissions. The following case studies were conducted:[1]

- Oxidation catalytic converters and three-way catalysts introduced in the US in the mid 1970s and early 1980s, respectively, in response to sharp reductions in emission standards (Chen et al, 2004a). These two cases were chosen because the incurred cost increases were much greater than for any other change in vehicle emission standards.
- Air bag requirement in the US in 1980s (Abeles et al, 2004). This passive restraint requirement was analyzed because it was the single most contentious and costly safety requirement imposed on the auto industry.
- Diesel cars in Europe (Chen et al, 2004b). This case study examines the voluntary adoption of a carbon dioxide emission standard and the industry's principal response: diesel cars.

[1] Battery electric vehicles were not included because they were never introduced on a large scale. Total BEV sales never exceeded a few hundred in any year, excluding small neighborhood electric vehicles.

- Hybrid electric vehicles in the US (Burke, 2004). The voluntary introduction of this energy efficient and low-emitting technology, beginning in the US in 2000, provides insight into how companies introduce unique new technologies, and how consumers respond.

These various studies of industry behavior are based on original analyses of published data, and draw upon the remarkably extensive public record of these regulatory interventions (i.e., transcripts of public hearings and coverage by mass media and trade publications) and the more modest professional and scientific literature. The analysis and interpretation of data were informed and guided by discussions with current and retired automotive executives and analysts. Analyses of consumer response to new regulations and technologies draw in part from these case studies as well as the extensive market research experience of the UC Davis research team and the broader literature on consumer response to energy and environmental vehicle attributes. The overall findings on consumer behavior are summarized in this report, and documented in Kurani and Turrentine (2004a).

Context and Caveats

This report addresses the relationship between very large and complex governments, a very large industry, and a highly diverse consumer population. The relationships are complex, often private, and evolving. The findings of this summary report and the accompanying volumes are subject to many caveats and need to be understood in context. Three broad contexts and caveats are highlighted here.

First, this study relates to current industry dynamics. The current automotive industry is very different from 40 years ago. In the early 1960s, three domestic companies dominated the US automotive market, accounting for nearly 100% of light duty vehicle sales. Now those three companies account for only about 60% of national sales (and less than 50% in California). The three companies have been steadily losing market share to automakers based in Asia and Europe, with Chrysler even purchased by a European company. The oligopoly of three firms has evolved into a highly competitive market. One outcome is less unified industry negotiating positions with regulators, more diverse responses to regulatory initiatives, and more diverse product offerings and pricing strategies.

Second, the history and experience of government regulation of the automotive industry is relatively recent. It is not a mature process. Government began seriously regulating motor vehicle attributes in the 1960s, beginning with safety. This “social” regulation, now addressing safety, pollution, and energy use, has evolved considerably. It is inherently a conflict-based process. Companies are called upon to develop and adopt new technologies that often have unknown costs and uncertain consumer responses, while regulators are adopting rules often with limited knowledge of what technological improvements are possible at what cost. This relationship between regulators and automakers has been steadily evolving. Both sides are becoming more knowledgeable about what is possible and desirable. At the same time, though, the focus of problems and the structure of the industry continue to shift.

Third, this report focuses on the large international automakers that dominate the industry. These companies have the capabilities and resources to invest in new products and technologies. But there are cases of small specialized manufacturers, and unprofitable companies of all sizes that can and have failed, or been bought by stronger companies, in part because of their difficulty in responding to increasingly stringent requirements. These cases are not well documented and are usually complicated by many other factors -- and are not addressed in this report.

HISTORICAL OVERVIEW OF REGULATIONS, TECHNOLOGY, PRICES, AND SALES IN US

As a first step in addressing how government regulations affect vehicle offerings and prices, we created a large database of vehicle prices, attributes, and sales from 1975 to 2003, by vehicle class and manufacturer, and supplemented it with historical data on income, economic conditions, fuel prices, and consumer financing factors (see Burke et al, 2004 for sources and details). Data were analyzed using SPSS, ACCESS, and EXCEL software to analyze historical trends of vehicle, price, and sales parameters in response to changes in government vehicle regulations. An overview of the various changes is provided below.

Vehicle emissions were first regulated in the early 1960s, beginning with the control of crankcase emissions. As indicated in Table 1, emission standards have been tightened over the years, and continue to be so – with new vehicles sold in 2003 having tested emissions 90- 99% below 1960s pre-controlled levels (though actual on-road emissions are higher).

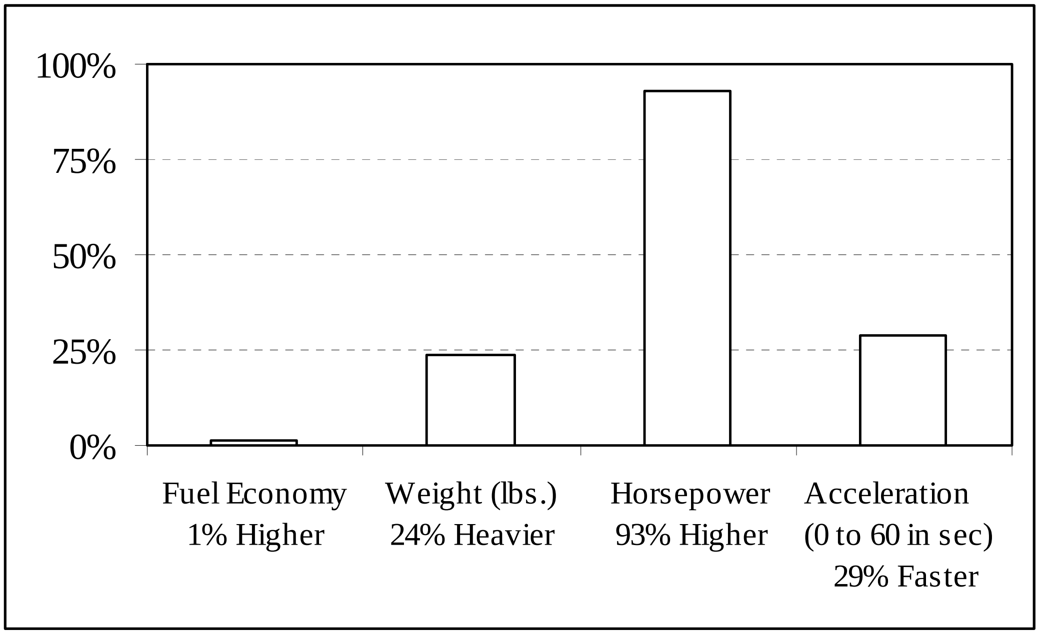
The tightening of fuel economy standards has been more modest in magnitude and more controversial. It is also instructive in demonstrating the powerful but not always straightforward role of standards in influencing innovation. CAFE standards for cars, adopted in 1975, required automakers to increase fuel economy of their cars from about 13 mpg to 18 mpg in 1978, and then to 27.5 mpg by 1985. The standards were met. But since then, the overall fuel economy of cars and light trucks has not improved at all – even though technical fuel efficiency improvements were being made and implemented. Indeed, tremendous improvements were made in engine efficiency, use of lightweight materials, and lighter designs, even during the last 20 years. But these improvements were not used to reduce fuel consumption; as indicated in Figure 1 they were used to increase horsepower (93% increase from 1981 to 2003), improve power (0-60 mph times dropped 29% from about 15 to 10 seconds), and increase weight (+24%), as well as add energy-consuming accessories such as all-wheel drive and air conditioning. If performance and size had been held constant from 1985 to 2001, fuel economy would have improved about 2% per year -- over 30% during this period -- instead of not at all (Hellman and Heavenrich, 2003). Fuel economy standards thus play an important role in motivating technical fuel-efficiency innovations, but how those innovations are used is part of a more complex story related to market dynamics, consumer behavior, and company positioning.

Table 1 California and Federal Exhaust Emission Standards for Passenger Cars (g/mi)

	Federal			*California*		
Model Year	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**
uncontrolled	8.7	90	3.4	8.7	90	3.4
1966				4.3	44	
1967				4.3	44	
1968	4.1	34		4.3	44	
1969	4.1	34		4.3	44	
1970	4.1	34		2.2	23	
1971	4.1	34		2.2	23	
1972	3.0	28		1.5	23	3.0
1973	3.0	28	3.1	1.5	23	3.0
1974	3.0	28	3.1	1.5	23	2.0
1975	1.5	15	3.1	0.9	9	2.0
1976	1.5	15	3.1	0.9	9	2.0
1977	1.5	15	2.0	0.41	9	1.5
1978	1.5	15	2.0	0.41	9	1.5
1979	1.5	15	2.0	0.41	9	1.5
1980	0.41	7.0	2.0	0.41	9	1.0
1981	0.41	3.4	1.0	0.41	7	1.0
1982	0.41	3.4	1.0	0.41	7	0.4
1983	0.41	3.4	1.0	0.41	7	0.4
1984	0.41	3.4	1.0	0.41	7	0.4
1985	0.41	3.4	1.0	0.41	7	0.4
1986	0.41	3.4	1.0	0.41	7	0.4
1987	0.41	3.4	1.0	0.41	7	0.4
1988	0.41	3.4	1.0	0.41	7	0.4
1989	0.41	3.4	1.0	0.41	7	0.4
1990	0.41	3.4	1.0	0.41	7	0.4
1991	0.41	3.4	1.0	0.41	7	0.4
1992	0.41	3.4	1.0	0.41	7	0.4
1993	0.41	3.4	1.0	0.41	7	0.4
1994	0.41	3.4	0.4	0.25†	1.7-3.4‡	0.2-0.4‡
1995	0.41	3.4	0.4	0.231†	1.7-3.4	0.2-0.4
1996	0.41	3.4	0.4	0.225†	1.7-3.4	0.2-0.4
1997	0.41	3.4	0.4	0.202†	1.7-3.4	0.2-0.4
1998	0.41	3.4	0.4	0.157†	1.7-3.4	0.2-0.4
1999	0.41	3.4	0.4	0.113†	1.7-3.4	0.2-0.4
2000	0.41	3.4	0.4	0.073†	1.7-3.4	0.2-0.4
2001	0.075†	1.7-3.4‡	0.2-0.4‡	0.07†	1.7-3.4	0.2-0.4
2002	0.075†	1.7-3.4	0.2-0.4	0.068†	1.7-3.4	0.2-0.4
2003	0.075†	1.7-3.4	0.2-0.4	0.062†	1.7-3.4	0.2-0.4

Notes: † Fleet average of non-methane organic gases
‡ Emission standard varies depending on certification levels (e.g., LEV, ULEV)
Sources: U.S. Environmental Protection Agency, California Air Resources Board, California Code of Regulations.

Figure 1 Percent Change from 1981 to 2003 in Average Vehicle Characteristics



Source: Hellman and Heavenrich, 2003

The light duty market evolved considerably over the past few decades, and continues to evolve. One underlying change was improved safety, emissions, and energy efficiency, all related to government rules and regulations. As indicated in Finding #1 below, the costs associated with these improvements are significant, but a modest part of overall cost increases. Other changes – improvements in reliability, durability, "fit-and-finish" quality, and power, and the addition of many new accessories – incurred even greater costs, and therefore were responsible for a larger proportion of increased vehicle prices.

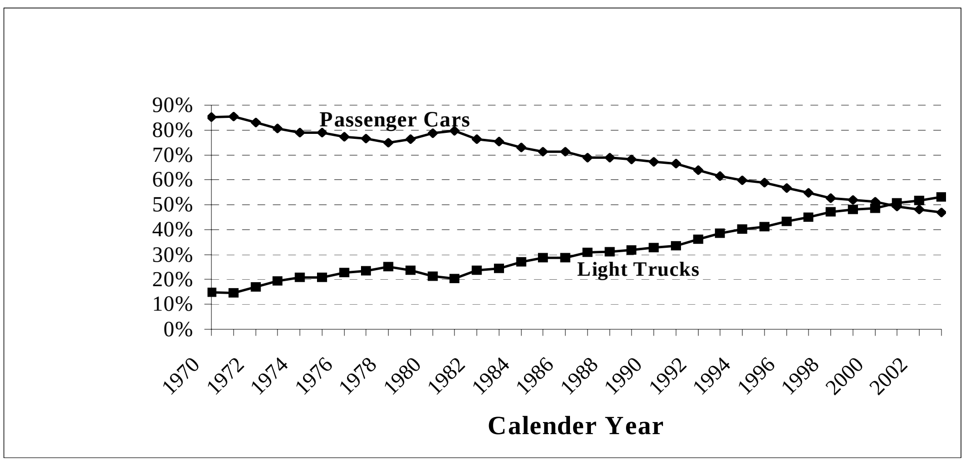
Cost increases are difficult to quantify. The best indicator of changes in costs are transaction prices estimated by the Bureau of Economic Analysis (BEA) of the US Department of Commerce through extensive surveys (with responses weighted by sales). The problem is that cost data are confidential and not available.

Many analysts use manufacturer's suggested retail prices (MSRP) as an indicator of prices, but these are not good indicators. They are not sales weighted and it is very difficult to procure sales figures by model for the 1970s and '80s. Moreover, automakers often increase MSRP intermittently over a year. Most importantly, consumers do not pay the MSRP. They pay more for extra features and accessories, or less if they negotiate a lower price or receive financing incentives. And special loan conditions alter the effective price they pay. And then there is the problem of adjusting for inflation. Two price indices are often used: the consumer price index and the vehicle price index. They are very different. For instance, the consumer price index (CPI) for all goods and services increased 105% between 1985 and 2003, but for new vehicles only 50%. If one is analyzing changes in vehicle prices over time, one should use the vehicle CPI, which produces smaller increases in vehicle prices than the general CPI. (One would use the general CPI when analyzing consumers' ability to buy new vehicles.)

In any case, as documented later, by any measure vehicle prices have increased considerably. In Finding #1, we examine what proportion of vehicle price increases were due to regulatory requirements.

Another profound shift over the past three decades has been the shift from cars to light trucks. As indicated in Figure 2, cars as a share of light duty vehicles dropped from 85% in 1971 to less than 50% in 2001 -- the remainder being light trucks. In 1975 most light trucks were pickups; by 2001, sport utility vehicles (SUVs) were the largest light truck category, accounting for 20% of all light duty sales.

Figure 2 Sales of Cars and Light Duty Trucks by Percentage, 1970-2003, US



Sources: American Automobile Manufacturers Association (1998), Ward's Communication (2003).

In a larger sense, though, the shift from cars to light trucks, and other shifts between vehicle classes are related to changes in vehicle prices, fuel prices, household income, economic conditions, and consumer financing costs. For instance, the large annual fluctuations in annual vehicle sales indicated in Table 2 closely tracked economic conditions (Ward's, 2003; US Dept of Commerce, 2003). In depressed economic times, consumers sharply reduced purchases of new vehicles, and in good times, increased purchases.

In summary, the automotive market is highly complex, with different companies pursuing different strategies and facing different market circumstances. Overall, vehicle prices in real dollars have increased significantly over the years due to both technology and quality changes in the vehicles, but consumers have continued to purchase the vehicles even at the higher prices. Much can be learned from the past, in terms of industry and consumer response to regulations, but those findings must be interpreted in terms of evolving circumstances if they are to provide useful lessons for the future. In the remainder of this report, we report the findings from our case studies and consumer research, and interpret them in terms of our understanding of evolving circumstances.

PROJECT FINDINGS

#1: Government regulations have accounted for about 1/3 of overall vehicle price increases.

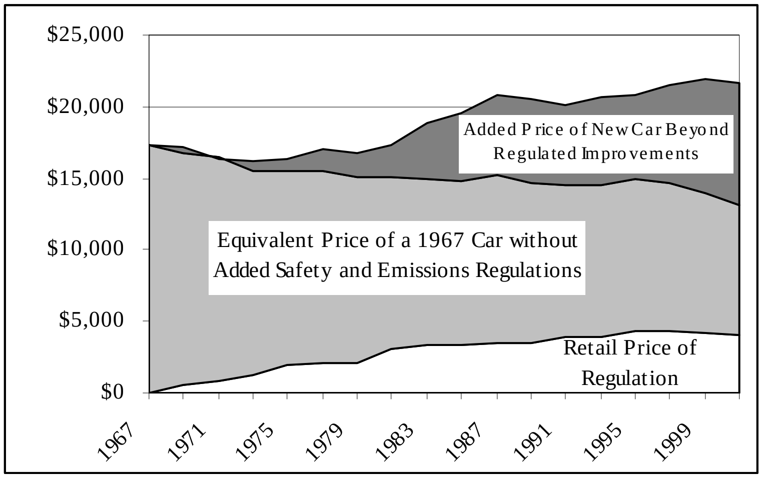
Government regulations to improve safety and reduce air pollutant emissions and oil use have added significant cost to vehicles. But how much – both in absolute terms and relative to the costs of other vehicle improvements?

This question is remarkably difficult to answer, mostly because of paucity of data on costs of complying with government regulations. The best source of aggregate regulatory cost compliance data is from the US Bureau of Labor Statistics (BLS), which annually estimates the cost of "quality improvements" to vehicles. They break these quality improvement costs into regulated and non-regulated improvements. Regulated improvements are for safety and emissions. We compare those cost estimates with average vehicle "transaction" price estimates by US Bureau of Economic Affairs (BEA), published in Ward's Automotive Yearbook (annual) to determine the proportion of vehicle price increases attributable to regulations.

Some analysts add the annual estimates of costs resulting from regulation into a cumulative total. That is incorrect. As noted above, there are sharp learning improvements with emissions and safety technologies, far more than with other non-regulated quality improvements since the non-regulated quality improvements tend not to be new technologies and not to have sharp learning improvements.

A better approach is to analyze data on quality improvements for current vehicles (see Figure 3). According to the BEA data (reported in Ward's), the sales-weighted average price of vehicles sold in 1967 was $3,200 in current dollars, including a very tiny amount (about $11) for regulatory quality improvements, for safety and emissions. If one applies the new vehicle price index (NVPI) to the 1967 price, the price of a car with identical quality would be $9,120 in 2001 in 2001$. But the actual 2001 price (from BEA) was $21,600. Hence, quality improvements and other cost factors between 1967 and 2001 account for $12,480 of the price of the 2001 car.

Figure 3 Average Transaction Price for a New Car in 2001$



Note: The light gray area represents the estimated average transaction price for a 1967 comparable car with no regulated or non-regulated quality improvements. The white area represents the value of added safety and emissions equipment as determined by the U.S. Bureau of Labor Statistics (BLS), all inflated to current dollars. Note that prior to 1980, the cost to improve fuel economy was included with quality improvements "beyond regulated improvements" (in the dark gray category), but since then has been included with the cost of regulation. The dark gray area shows the change in transaction price accounted for by non-regulated improvements plus other quality and price increases.
Source: BEA and BLS data as reported in Ward's (annual).

Separately, Ward's, using BEA data, estimates the total price of improvements due to regulations for 2001 cars to be $4020. Thus, regulations accounted for about 1/3 of the price increase between 1967 and 2001. The ratio between 1975 and the present would also be about 1/3.

We believe that the cost estimate of $4020 per vehicle to meet emissions and safety regulations to be high. One industry expert contends that safety and emissions regulations added about $2,500 to the price of an average new car in 2000 (Weidenbaum, 2000, p. 14). We believe this number to be closer to reality.

As indicated in Finding #2, the cost of emission control is no more than $1000 per vehicle. We did not conduct a similarly comprehensive analysis of safety costs, but did examine airbags, the costliest safety item in the vehicle. Since 1999, dual airbags have been required for all light duty vehicles sold in the US. Additional airbags are beginning to become widespread on vehicles. We consider the cost of dual airbags as automaker responses to regulations, though we note that airbags are now more a response to market demand than regulatory requirements.

There was significant debate over the cost of airbags in the early years. A teardown analysis in 1988 of airbags for the Ford Tempo determined that the cost for a Ford driver-side airbag was $391 at a production rate of 350,000 units, and $1,233 at 25,000 units (2002$) (Khadilka, 1988). Ford offered the airbags on 1987 and 1988 Tempos and Topazes as an option for $815 ($1,233 in 2002$), but sold only about 13,000 and reported that they suffered significant losses (Automotive News, 1988). By 2000, volume was dramatically higher and costs had fallen accordingly. Another teardown analysis employing the same methodology found that a driver-side airbag on a 2000 Ford Taurus had a cost of about $180 (2000$) at a production volume of 250,000 units (Spinney, 2000). In fact, Ford inserted these airbags in their 382,035 2000 Ford Taurus's and similar versions on all of the company's 4 million 2000 passenger cars and light trucks sold in the US.

Thus, the cost of dual airbags in 2000 was several hundred dollars. Doubling these costs to reflect retail prices, and adding in other safety features is unlikely to boost the average safety cost per vehicle much beyond $1000.

In summary, the BLS estimate of $4018 per vehicle for regulatory compliance seems overstated, and thus the estimate that emissions and safety regulation accounted for 1/3 the cost of vehicles over the past few decades should be treated as an upper limit.

#2: Cost of complying with emission standards peaked in the 1980s.

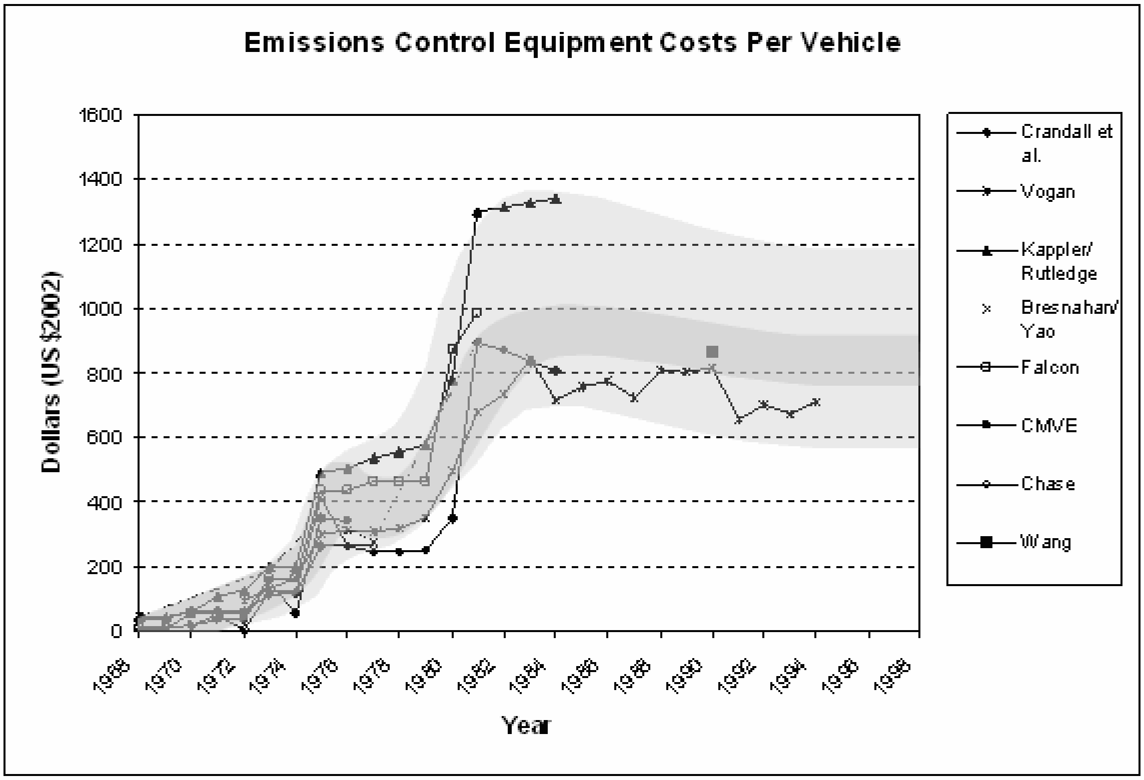
Our detailed analyses of emission control costs suggest that cost per vehicle peaked in the early 1980s and only now in 2004 are starting to approach those levels again.

Emission control cost calculations are difficult and uncertain. Emission control costs should include research and development expenditures as well as new tooling machinery in factories to build the new control devices, but untangling those costs from other R&D and manufacturing costs is difficult because vehicles are designed as integrated systems and a single vehicle part may serve multiple functions (e.g., electronic fuel injection improves performance and energy efficiency, as well as emissions). Moreover, costs vary depending on vehicle weight, engine design, and engine calibration, and also by manufacturer.

A number of cost estimates have been made of emissions control systems, each using different methods (Figure 4). They indicate that the cost per vehicle for emission control jumped in 1975, mostly because costly catalytic converters were needed to respond to tightened hydrocarbon and carbon monoxide standards, and again in 1981, this time with three-way catalysts and electronic controls, motivated by the need to meet tightened nitrogen oxide standards. Estimates of emission control costs per vehicle for 1981 range from $875 to $1350 (US$2002).[2] These costs subsided thereafter, well into the 1990s as continuing improvements were made in design and manufacturing (see Finding #4 regarding innovation effects).

[2] Strictly speaking, these emission control "cost" values are actually retail values – that is, cost to the consumer – and thus are directly comparable to vehicle prices.

Figure 4 Emissions Equipment Control Costs, 1968-1998



Note: Compliance costs associated with emissions regulation vary widely depending on manufacturer and vehicle size. The lightly shaded area represents uncertainty in average control costs. The darker shaded area represents our best assessment.
Source: Chen et al, 2004a (based on cited studies)

Beginning in the early 1990s emission control costs began to increase once again, the result of new (Tier 1 and LEV I) standards adopted in 1990 by California and the US EPA. Retrospective analyses by the California Air Resources Board staff suggest that the cost of reducing emissions from 1990 levels to “ultralow” levels (California’s ULEV standard) was about $200.

The net result is that about $1000 of the retail cost of today’s vehicles is incurred to meet emission standards -- roughly the same cost that was incurred in the early 1980s, when emission standards were far less stringent.

One study provides additional insight and detail. Wang et al. (1993) used a parts-pricing approach on model year 1990 vehicles to find that emissions control costs vary widely depending on vehicle class and manufacturer. For example, US manufacturers spent only $250 (US$2002) on average for emission control per compact car, while European manufacturers spent $1680 per vehicle for large cars.[3] In general, that study found costs

[3] These costs are costs to the manufacturer. To convert them into costs to the consumer (and to make them comparable to other emission costs presented elsewhere in this report), they should be inflated about 40% to represent manufacturer and dealer markups.

were less for smaller vehicles, more for Japanese manufacturers presumably because they were more risk averse and aimed for a larger buffer below the standard, and more for Europeans automakers who supplied a greater share of luxury cars with presumably smaller economies of scale and higher quality. Since 1990, circumstances have changed, but significant cost differences presumably still exist across engines and vehicles, and probably manufacturers as well.

#3: Cost increases associated with regulations have been swamped by year-to-year variability in vehicle price.

Because of long time lags in implementing new government rules (often due to industry challenges) and continuing R&D, and in some cases strong consumer demand for new safety devices, automakers have not experienced large cost shocks in any single year. Having said this, we are not endorsing delay; long delays and uncertain requirements are not a model of good rule-making. In many cases, regulatory delays and uncertainty resulted in inefficient investments by industry as they tried to gauge uncertain market demand and uncertain implementation of government rules. The result was more pollution and more fatalities over those years.

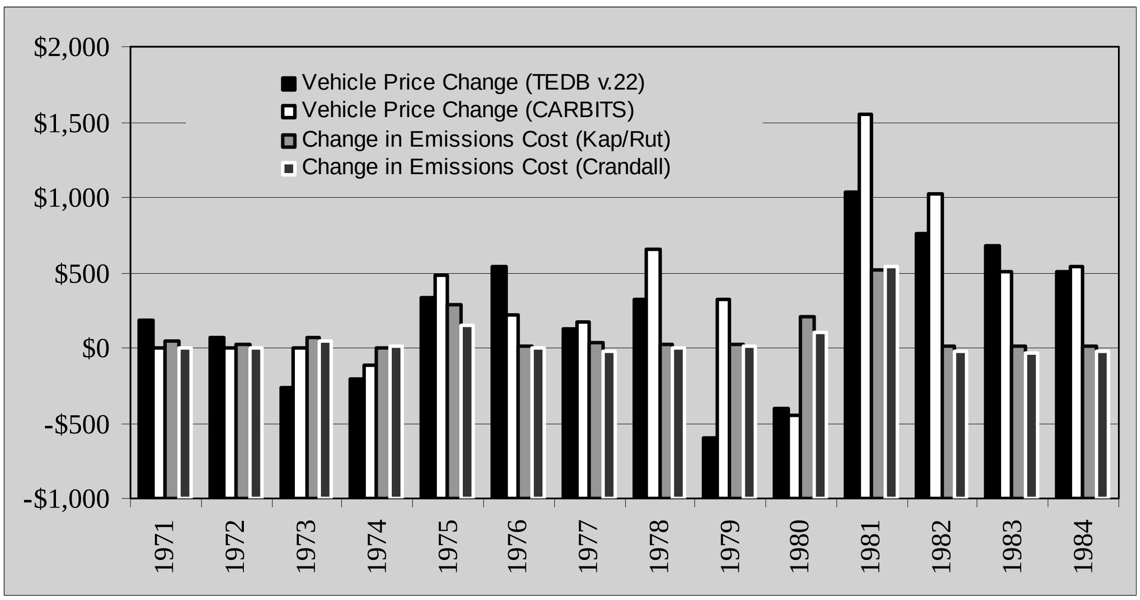
The more specific point here is that, while regulatory compliance costs have been substantial and influential, they have not played a significant role in the pricing of vehicles. Vehicle prices have steadily increased over time, far exceeding the costs of emission control and safety equipment. These price increases have fluctuated considerably on a year-to-year basis. These two effects, price increases and price fluctuations, tend to swamp typical compliance cost increases for emission control and safety – even, as we have seen, when regulatory compliance costs have been especially large. These cost increases, to the extent they are substantial, are dealt with in the short run by a variety of pricing and marketing strategies and by allocating R&D costs further into the future and over more future models.

Indeed, even during those times when large new emission and safety costs were imposed (for catalytic converters and air bags), prices for particular models and even vehicle classes fluctuated considerably, both up and down. During some years, vehicle prices declined for one class but increased for another. During the volatile 1979-80 period, the average price of a subcompact car increased by $465 while midsize car prices decreased by over $2000 (2002 dollars). In recent years, financing incentives and sales rebates have introduced even more price variation – not necessarily in terms of the manufacturer's suggested retail price (MSRP), but in actual prices paid by customers. For instance, in 2002, GM offered an average of $1500 per vehicle in financial incentives, including $3,855 per vehicle in the third quarter of that year (Automotive News, 2002).

In comparison, annual changes in compliance costs for emission and safety standards over most of the last three decade have been rather small. In only a few years over the past 35 have increases in emission costs exceeded the change in vehicle price (the number of years depending on study method and data used) (Abeles et al, 2004; Burke et al, 2004; Chen et al, 2004a).

The response of automakers in 1975 and 1980-81 is instructive, since this is the time when emission control costs increased most sharply – $300-$500 per vehicle in a single year. Figure 5 compares emission costs to vehicle price for these periods. In those two time periods of interest, vehicle price increases were considerably greater than emission cost increases. Was the intent to completely recover costs immediately? Probably not, for reasons we elaborate below. These were volatile times for the industry, with fuel prices rising sharply and, in the 1980-81 period, aggressive CAFE standards taking effect.

Figure 5 Change in Vehicle Price vs. Change in Emission Control Costs, US, 1970-84



Source: Chen et al, 2004a

In summary, in most years, the effects of emission standards on vehicle prices cannot be detected. When the costs were significant, other cost and pricing factors seemed to be even more important. The added compliance costs associated with emission reduction are just one more factor used by companies in setting prices. And thus, aggregate new car sales have been affected only in a minor way by safety and emissions regulations.

Finally, the effect of emissions and safety regulations on overall vehicle sales is speculative. Emissions and safety regulations clearly added cost to vehicles, but they also added value. Without those rules, vehicles would be more dangerous and more polluting – but less costly. Without the government regulations, it is unknown whether overall demand for vehicles would be more or less.

#4: Technological innovation dampens the cost of complying with new regulations.

New regulations that improve vehicle safety and environmental and energy performance also impose additional costs. But these additional costs are not permanent nor cumulative. As with any new products or technologies, with time and experience engineers learn to design the products to use less space, operate more efficiently, use less material, and facilitate manufacturing. They also learn to build factories in ways that reduce manufacturing cost. This has been the experience with semiconductors, computers, cell phones, DVD players, microwave ovens – and also catalytic converters and airbags, and will certainly be the case with future technologies such as fuel cells.

Experience curves, sometimes referred to as "learning curves," are a useful analytical construct for understanding the magnitude of these improvements. Analysts have long observed that products show a consistent pattern of cost reduction with increases in cumulative production volume. In essence, manufactured products tend to decline in cost by 10-30% with each doubling of *cumulative* production volume (see Lipman and Sperling, 2000). This logarithmic effect means that cost reductions are achieved rapidly early in a product's history, when doublings in cumulative production occur relatively quickly, and then more slowly as the doublings take longer to achieve. Thus, if a product can gain an initial foothold in the market due to some competitive advantage – or government regulation -- this triggers a cycle of innovation that results in continuing cost reductions.

Innovation tends to reduce costs over time, as is the case with emissions and safety improvements -- though continuing tightening of standards can introduce more cost. In the case of emissions, learning improvements have been so substantial, as indicated earlier, that emission control costs per vehicle (for gasoline internal combustion engine vehicles) are no greater, and possibly less, than they were in the early 1980s, when emission reductions were far less (see Table 1).

In practice, the relationship between regulations and innovation is complex and far reaching, with substantial positive indirect effects. Tightened emissions and fuel economy standards played a central role in motivating the development of an impressive array of new and improved technologies that were rapidly introduced in passenger cars starting in the mid 1970s, continuing to the present time. Many of these innovations would have eventually been introduced without the standards, and many provided a wide array of benefits and enhancements. These innovations included engine and fuel sensors, computers, electronic ignition control, lightweight materials, four valves per cylinder, variable timing, cylinder deactivation, and rapid engine stop-start. Indeed, the adoption of aggressive emissions, energy, and safety requirements in the 1970s is often credited with accelerating innovation in the automotive industry (Maynard, 2003). Those standards may also have aided the competitiveness of the domestic auto industry by forcing it to innovate earlier than otherwise, giving it more time to respond to the newly competitive foreign competitors (Kawahara, 1998). In any case, the rate of innovation in the auto industry began accelerating in the 1970s (Santini, 1985 and rapid innovation continues to the present day, with a host of innovations, including hybrid-electric powertrains, aimed at improving energy and environmental performance.

#5: Compliance costs are not immediately converted into higher price and are recovered with a variety of ad hoc tactics.

As a general principle, companies want to pass costs through to consumers as fast and fully as possible. In practice, though, the costs of complying with regulations are not immediately passed through to customers in higher prices, nor are costs passed through equally to all new vehicles and classes.

Using a model of vehicle prices and profits they developed, Robert Crandall of Brookings Institution and his colleagues (1986) found that automotive manufacturers fully absorb additional regulatory costs in the first year and then pass on approximately two-thirds of the costs to consumers the following year. They note that the full costs of regulation may eventually be included in the price of the vehicle. In his report on corporate strategies of automakers, Schnapp writes, “[t]here will be an inevitable tendency to pass through regulatory cost increases despite automaker concerns about possible adverse consumer behavior” (Schnapp, 1978, p. I-91). Economists, viewing compliance costs as analogous to a unit sales tax on the industry, assert that competitive firms should be expected to pass on as much of this “tax” as possible, since subsidizing consumers indefinitely would reduce profit margins.

One phenomenon mitigating the rapid pass-through of costs are innovation effects, as indicated in Finding #4. With time and experience, the cost of making and installing catalytic converters, sensors, airbags, and so on is reduced.

Another phenomena, a deliberate strategy used by automakers to restrain price increases, is decontenting. In this case, automakers convert standard equipment into optional equipment, replacing materials such as tires, fabric, and carpet with inferior substitutes, or eliminating some features altogether, such as vent windows or arm rests (Braden et al, 1979, p.100).

More broadly, vehicle pricing is a complex art in which prices are only loosely connected to costs. In setting prices, automakers consider not only production costs, but also overall return on investment, sunk costs, expected sales, shifting consumer demand, prices of competing new and used cars, long term buyer loyalty, and market conditions.

Pricing strategies generally fall into three categories: cost, image, and competitive pricing. Cost pricing bases the price of a vehicle on the price of other models in the same vehicle segment with any necessary adjustments made for actual production costs. Base vehicle prices and option prices fall within a narrow margin among the manufacturers (Braden et al, 1979, p.30; Kawahara, 1998). This approach was dominant until the 1970s. Image pricing bases the price of a vehicle on its appeal within the market. Luxury models and, more recently, SUVs are typically priced using this method.

The SUV phenomenon, along with light duty trucks more generally, are particularly instructive in highlighting the complexity of pricing – and, by extension, the small role of regulatory compliance costs. In 2000, a fully loaded Lincoln Navigator was estimated to earn as much as $15,000 profit per vehicle (Bradsher, 2002, 85). One single factory, where the large Ford Expedition and Navigator SUVs were assembled, generated $2.4 billion in after-tax profits in 1998, one third of the company's entire profit for the year (Bradsher, 2002: 89).[4] Similarly, while it cost Ford about the same amount to build their Taurus sedan as their full-sized pick-up, they priced the pick-up $5000 higher (Rubenstein, 2001, 241).

A third approach is competitive pricing. This broad category encompasses the many other tactics used in pricing. One tactic is to lower prices of entry-level vehicles so as to attract new customers, with the hope they will become loyal to the brand and move up later to more profitable models. Another tactic is to price vehicles with high fuel economy lower so that they can sell more high-profit luxury cars (with low fuel economy).

Another competitive issue affecting pricing has to do with what have become known as legacy costs. The historical US companies -- General Motors, Ford, and Chrysler -- have a legacy of many manufacturing plants, longstanding labor contracts, and a large number of retirees. They are burdened by the high cost of health insurance and pensions for these many retirees, find it difficult to dispose of existing facilities, and are limited by labor contracts that require them to continue paying laid-off workers (Bradsher, 2002: 91). As a result, these three companies have a large incentive to resist further erosion of their market share, and to price their product accordingly – that is, to price vehicles low enough to ensure high sales (Rubenstein, 2001).

Neither the literature nor industry analysts provide a framework that explains automaker pricing behavior, and nowhere did we find evidence of formal quantitatively based scientific strategies. Our interpretation of the case studies and various discussions with executives and analysts suggests that companies pursue the following general guidelines:

- Restrain price increases
- Increase prices for products where demand is less sensitive to price increases
- Maintain sufficient sales volume for vehicles with good fuel economy so as to avoid CAFE fines
- Design (and fine tune) vehicle prices to achieve sales targets, which had been used to design and retool factories for that product and to manage labor needs.
- Pass costs upstream to parts suppliers as much as possible.
- Identify regulatory and policy "loopholes" to avoid costs and enhance profits.

Of course, companies might employ a wide variety of tactics in responding to these guidelines. They might increase the price of after-market parts, reduce the number of options available, "decontent" vehicles, and offer longer term financing to customers.

[4] Auto manufacturers do not publish profits broken down by individual model or assembly plant. They do, however, give special briefings to Wall Street analysts on costs and profits, and these analyses sometimes find there way to journalists, such as Keith Bradsher of the New York Times, who disclosed these analyses in his book.

In a broader sense, companies may increase prices across their fleet or for selected makes and models, introduce costly changes only on certain vehicles or in certain markets, and change the mix of vehicles offered. Indeed, as a means of pursuing profits in a highly competitive and shifting market, automakers are constantly readjusting their vehicle mix, vehicle options, pricing, and financing incentives.

It is well known that automotive companies cross-subsidize certain vehicles on a sustained basis -- to attract new customers to their entry-level cars in anticipation that they will later move up to more profitable vehicles, to create a vehicle mix that will help meet the company's CAFE standards, and to boost sales and recoup huge upfront investments for products not meeting planned sales targets.

Pricing is also influenced by the huge upfront investment required to launch new models -- upwards of a billion dollars. To maintain profitability in a complex business environment of high fixed costs, unpredictable economic conditions, and varying consumer tastes, companies employ a wide variety of manufacturing, marketing, advertising, and financing strategies.

In summary, vehicle pricing is only loosely connected to costs. As a general principle, automakers try to recover costs of complying with regulations as quickly as possible. But cost recovery strategies vary according to a wide variety of circumstances, and are generally dwarfed by other considerations. It is instructive to note that in some years, vehicle prices actually dropped when emission costs increased (see Figure 5).

#6: Manufacturers spread the cost of new technologies across a broad range of models and markets.

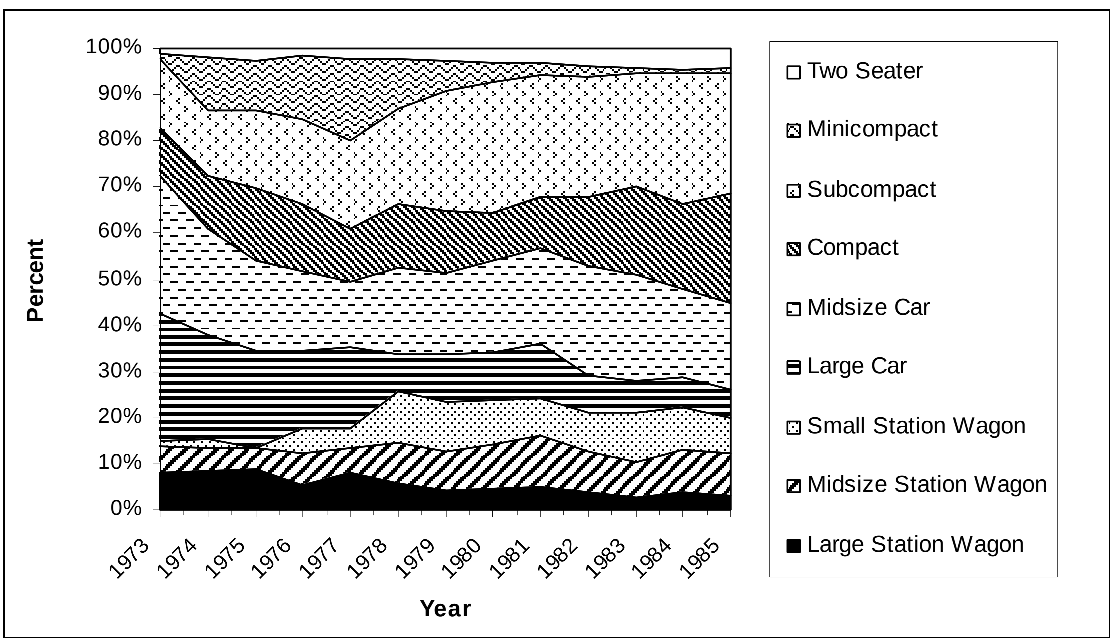
During the intermittent and often contentious zero emission vehicle debates in California, automakers sometimes asserted that the high cost of producing battery electric cars, well above what customers would be willing to pay, would obligate them to raise the prices of all vehicles sold in California to compensate them for the extra cost. The more general question is whether automakers try to recover cost increases in the same regions where they sell the new costly products, whether sold voluntarily or not? It is a relevant question when the new product has high R&D and/or upfront tooling expenses. This question might apply to a wide range of products, such as hybrid vehicles sold disproportionately in Japan and California, cold weather features designed for Alaska and Canada, and emission controls designed for Denver and other high elevation locations.

We found no evidence that automakers make a strong effort to recover costs of new expensive products in the same regions where they sell them, at least initially. For instance, vehicle prices in California in 2003 had the same MSRP as vehicles sold elsewhere in the country, even though cars sold in California had to meet more stringent emission standards (though the differential was not great). One exception highlights the point. Ford sells a version of the Focus in California that meets stringent PZEV (partial zero emission vehicle) requirements. They offer the same vehicle elsewhere in the country, but with the PZEV option priced $115 extra. The actual cost increment is much greater. The additional cost for emission control is estimated by CARB to be about $100, but this PZEV car not only has extra emission control, but also is fitted with a more powerful engine. Jim Cain, a spokesperson for Ford, said, "We only charge $115 for several hundred dollars' worth of improvements… The Focus competes in a very price-sensitive segment of the market. If we charge too much money, we might not achieve our volume objective" (Wired, 2003). And thus, even if customers buy the PZEV model, Ford is not recovering the extra cost of emission control, and is essentially spreading the cost increment broadly across its customers (and stockholders).

#7: Regulations sometimes induce manufacturers to alter their volume and mix of vehicles.

Vehicle attributes and vehicle mix are not static (see Figure 6). Large station wagons virtually disappeared in the late 1970s, minivans emerged as a new vehicle class in the early 1980s, sport utility vehicles increased their share from near zero in the early '90s to almost 20% in 2002, and in the early years of this century, a variety of crossover car-truck models are being launched. Clearly, the automotive industry has a history of being able to transform their product offerings in periods of less than a decade (though companies generally prefer more stability).

Figure 6 Distribution of Carlines by Vehicle Class



Source: Chen et al, 2004a.

We found only three cases where regulations clearly altered the volume and mix of vehicles. The first is in the late 1970s and early '80s. In Figure 6, one can see the continuing shifts in vehicle mix during this period. Subcompact and compact cars increased from ¼ of all cars in 1970 to half in 1981. During this period, stringent emission standards were adopted. But it also the period when fuel prices more than quadrupled and were expected to continue increasing, and fuel economy standards were imposed. CAFE standards played an important, though controversial role in this shift to smaller cars, along with large fuel price increases (Greene, 1990). During that time, John Deaver, manager of Ford's economics department, noted that "product mix decisions are now determined by the number of large and medium-sized cars the company believes it can sell, and then by the number of small cars it needs to produce/sell in order to meet CAFE requirements" (quoted in Schnapp, 1978, p.I-123). There is no evidence that the shift to small cars took place because of the newly stringent emission standards. -- even though emissions can be reduced more easily and less expensively in smaller cars (Wang et al, 1993).

CAFE standards played a role again, later, in influencing product mix, this time encouraging the introduction of minivans, pickup trucks, and SUVs. In this case, safety and emission standards also played a small complementary role. This time period was the 1980s and thereafter.

In 1980, cars accounted for 80% of light duty vehicles; by 2001 the share was less than 50% -- the remainder being light trucks. In 1980 most light trucks were pickups; by 2001, sport utility vehicles (SUVs) were the largest light truck category, accounting for 20% of all light duty sales. Regulations played some role in this shift, though no rigorous analysis has ever been conducted. Emission and safety standards were less stringent for light trucks than cars throughout this time period, and perhaps played some role in encouraging a shift to light trucks (Kockelman, 2000). But the more important effect was CAFE standards. Aggressive CAFE standards for cars, along with high fuel prices, played a central role in the demise of large station wagons in the late 1970s, while the more lenient CAFE standard for light trucks, along with dropping fuel prices,[5] encouraged manufacturers to emphasize minivans in the 1980s, and then SUVs in the 1990s

CAFE standards certainly played an important role in the emergence of light duty trucks. But other policy and market factors played an even stronger role. Perhaps the strongest indicator of these other factors was the huge profitability of SUVs in the 1990s. As indicated earlier, Ford's SUVs and large pick-up trucks were far more profitable during this era than cars. This high profitability was an outcome of industry dynamics and government policy. Japanese and European automakers did not have large markets for light trucks in their home markets (because of high fuel prices, dense cities, and so on) and thus were slow to enter this market. And a variety of policies helped created this market and high profitability. Less stringent CAFE, emission, and safety standards for light trucks played a role (larger SUVs are not even covered by CAFE and some safety standards). But also important was the US government adopted protectionist policies that

[5] Gasoline prices increased from $1.14 per gallon (for leaded regular) in 1972 (in 1996 dollars) to $2.21 in 1981 (for unleaded regular), dropping steadily to $1.23 in 1986, and then continuing along with small fluctuations to $1.23 in 2002. (U.S. Department of Energy, cited in Burke et al, 2004).

discouraged the importation of these vehicles, creating the potential for high profits. The US government imposed a 25% tax on all light trucks in 1964, and did not reduce it until 1989, to 2.5% for SUVs and minivans, leaving the 25% tariff in place on pickups.

A third case where regulations had an effect on product mix is the emergence of diesel cars in Europe. Diesel vehicle sales in the European Union (EU) increased from 23% of all light duty vehicles sold in 1994 to 41% in 2002. This rapid increase in market penetration was due to four related factors: a voluntary agreement by European automobile manufacturers in 1998 to reduce CO_2 emissions from new light duty vehicles by 25% from 1995 levels by 2008; significant advances in diesel technology; preferential fuel and vehicle pricing in most European countries; and preferential European Union regulation of diesel emissions (Chen et al, 2004b).

The voluntary agreement and the preferential emission standards were key. It was explicitly understood that if automakers did not meet the goals of the voluntary agreement, then firm enforceable rules would be put in place. Automakers determined from the outset that the easiest and cheapest way to meet the goals was largely by switching vehicles to the more efficient diesel engines. The EU supported these corporate plans by accelerating the introduction of clean diesel fuel (thereby allowing diesel cars to meet emission standards more easily) and permitting diesel cars to meet less stringent emission standards. As documented in Chen et al (2004a), light duty diesel emission standards in the EU are several times higher than gasoline standards for both nitrogen oxide and particulate emissions (per vehicle kilometer). In contrast, in the US and California, diesel cars and light trucks must meet the same stringent emission standards as their gasoline counterparts. The result of these aggressive CO_2 and diesel-friendly policies and rules is the transformation to diesel cars. Diesel cars are widely expected to exceed 50% of light duty sales in the EU by the end of this decade.

These three cases are instructive. They highlight the few but influential cases where government regulations and related policies have significantly impacted the mix of offerings by automakers. But it is instructive to note that in each case, the government regulations and policies were operating in unison with shifts and differences in fuel prices. In the shift to small cars, fuel prices were soaring. In the shift to light trucks, fuel prices were dropping. And in Europe, diesel fuel prices were much lower than gasoline prices.

#8: Manufacturers have used non-pricing strategies to overcome consumer resistance to price increases resulting from regulations.

When a new product or attribute has perceived value in the marketplace, that company will try to take advantage of it. When Chrysler became the first non-luxury automaker to offer airbags across their entire vehicle line, the move was supported by a memorable print and television advertising campaign. TV ads included:

- A live stunt driver crashing into a barrier with him hitting the airbag in slow motion, and then getting out of the car nonchalantly as if he had just stopped at the grocery store.
- Lee Iacocca sitting with survivors of horrific crashes that attributed their survival to the airbag in their Chrysler vehicle.
- A re-enactment of the post-crash scene of two Chrysler LeBarons that had suffered the first known head-on collision between two airbag-equipped cars.

Advertising can be effective to a point. It can help generate sales when the product is in line with consumer preferences, as with SUVs and airbags in the 1990s, but not when consumers are fundamentally disinterested, as with fuel efficient cars during the same time period. And when the product is perceived as inferior or poor value, as with GM's Vega in the 1970s, even heavy promotion is ineffective.

Another non-pricing strategy is lengthening of loan payback periods, making increasingly expensive cars more affordable. The average maturity rate for auto loans has nearly doubled, from 35 months in 1971 to 60 months in 2003. A number of independent finance companies in the western United States have recently offered loans as long as 96 months (Automotive News, 2003).

More broadly, automakers and dealers have increasingly turned to financing incentives to maintain high sales volumes during economic downturns. Since September 11th, 2001, General Motors has led the industry in expanding the use of zero percent financing and rebates. By October 2002, GM, Ford, and DaimlerChrysler were spending an average of $3,764 per vehicle, or 14 percent of the selling price, on all types of incentives (Automotive News, 2002).

Cut-rate financing and cash rebates are not new for the auto industry. These measures began in the mid-1970s as a means to move end-of-the-year inventory and particularly slow-selling models. Such marketing approaches have remained a way to reduce inventory and maintain market share. The excess capacity in the auto industry, particularly for GM, Ford and Chrysler, explains the need for those companies to maintain sales. Utilization of US automotive plant capacity has dropped from around 60% in the late 1980s to the high 40s in the early years of this century. Bill Lovejoy, V.P. of GM, stated in October 2002 that, "incentives will stay in place until demand is more aligned to capacity" (Automotive News, 2002). With the Japanese and European companies building new plants in the US, but total vehicle sales remaining flat, pressure on GM, Ford, and Chrysler to maintain sales and market share becomes more severe.

#9: Industry behavior toward new technologies is not related to whether or not they were the result of government regulation.

Companies adopt and promote new products and attributes based on their marketability, profitability, and market positioning strategy. If they are required to adopt it, and they perceive no market value in it, they will of course do whatever they can to minimize their investment and losses, short of tarnishing the brand. Thus, GM purchased slightly retrofitted golf carts and gave them away in California in 2002 as a way of meeting their ZEV requirements at least cost. They did not associate their name with the product in any way. Likewise, companies aggressively resisted airbag requirements for years because they believed the cost would be large and the perceived customer benefits small. When consumers began to value safety in the 1990s (and costs came down), car companies warmed to airbags and aggressively advertised and promoted them.

In the early years of this century, Toyota widely promoted its Prius hybrid electric car in print media and billboards, even though demand continued to exceed supply. They did so because it gave the company a halo effect – an image of environmentalism and advanced technology.

#10: The effect of fuel cost savings on vehicle purchase decisions is poorly understood.

Using an economic model to explain consumer behavior, the automotive industry and various studies have concluded that car buyers demand a three-year payback for fuel-saving investments (see Kurani and Turrentine 2004a for elaboration). Sometimes these findings are couched in terms of "discount" rates (a three-year payback being equivalent to a 30-40% implied discount rate). The underlying theory is consumers calculate how long it will take to get back money they spend on buying an alternative fuel or fuel-efficient vehicle. For example, suppose the consumer estimates that a more economical vehicle will cost $600 more to buy, but that he or she will save $200 per year in fuel costs. Their payback period would be three years. A more sophisticated approach would use discount rates, to analyze the opportunity costs of the additional upfront expenditure for the more expensive but economical vehicle, or even to consider differences in maintenance costs, refueling inconvenience, and other related factors.

This idea that consumers use payback periods or discount rates in making decisions is not widely accepted outside economics. Even the idea of payback calculations is seldom observed in household decision-making. Consumer researchers, particularly those looking at energy using appliances have argued that such calculations are beyond most consumer decision capabilities (Stern, 1992; Chater et al, 2003) and do not fit with cultural models of behavior (Kempton et al, 1995). In practice, consumers do not expect financial payback on vehicle attributes. Few vehicle attributes seem to be viewed in this rational economic way, and few consumers think this way. For example consumers do not expect financial payback on leather seats, acceleration or safety. A possible exception is reliability, but even here, consumers are more likely to search for a reliable brand or reputation than they are to make any calculations.

In a detailed study of vehicle purchases by over 50 households currently underway at ITS-Davis, we find that few households know their annual fuel costs, fewer still could or would make comparisons between vehicles based on payback, and none characterized purchase decisions in terms of opportunity costs over time (Kurani and Turrentine, 2004b). Many participants do not know the fuel consumption (miles per gallon) of their current vehicle and few households budget the cost of fuel. The one thing most car buyers do know is the cost of a filling their fuel tank (though many do not know how many gallons are in a tank nor how many miles they travel with a tank full of fuel).

Much of this inattention to fuel use may be due to the relatively small cost of fuel for most households. When pressed to state a payback period related to higher fuel economy, many households have been unable to estimate or even imagine one. Most commented that they had never thought about payback periods, and imagined that they would have to “do some math.” One financial analyst responded to our questions about the possible role of fuel savings in his household’s vehicle purchases, saying, “Oh, you mean the payback period. I never thought about it (fuel economy) that way.”

What is clear is that no household in their sample, not even those who understand the calculations to find a payback period, ever actually made such calculations about fuel costs for their automotive purchases. If they do offer a payback period, they arrive at a number in one of a number of ways, including the following:

- Length of time they financed a recent vehicle (typically three to five years)
- Length of a lease of a current vehicle (often five years)
- Length of ownership of a vehicle (depends on household and vehicle)

Some are optimistic, imagining they spend much more on fuel per year than they really spend and that paybacks are possible within one or two years. None mention discount rates for future fuel savings.

Similarly, attempts to "measure," and therefore to establish, consumer payback calculations or discount rates for diesel markets in the 1980s in the US or 1990s in Europe are off the mark in a similar way, and lack direct investigation of consumer decisions.

Based on this new research, we believe that consumers do not use the concept of an average payback period in making purchase decisions. It is not a valid measure of consumer awareness, knowledge, or use of fuel economy information, and probably represents a diverse set of unformed and *ad hoc* responses to an unfamiliar and inappropriate question. And there is no grounded behavioral evidence that a three year payback period describes behavior in an aggregate manner nor for an individual.

Similarly, attempts to measure and calculate consumer payback periods or discount rates for diesel car buying in the US in the 1980s or in Europe in the 1990s are off the mark in a similar way. They lack direct investigation of consumer decisions.

Improved understandings of buyer behavior are critical to predicting consumer response to new greenhouse gas emission standards, since new technologies and attributes will often be tested and introduced sequentially into particular vehicles in particular geographic markets to particular buyer segments. It is especially critical to the formulation of policy and regulations.

#11: Demand for environmental attributes in vehicles is weak -- and poorly understood.

Currently, little is understood about demand for environmental attributes of vehicles. Surveys show strong policy support for air pollution (Public Policy Institute, 2002), but how might that air pollution concern evolve into demand for cleaner vehicles? And how might other even less salient environmental and energy concerns -- for energy security and climate change -- evolve into stronger policy and buyer demand? The answers are entangled in deeper values and preferences related to consumer sovereignty, collective choice behavior, and environmental quality that vary across regions, social groups, and even nations. The problem is that these values, beliefs, and behaviors are not well understood, and thus it is difficult to assess how governments might best intervene – for instance via laws such as California's AB 1493.

The analytical difficulty is that vehicle buyers have rarely faced the choice between products offering *only* different levels of performance on environmental measures. Those cases in which it appears consumers may have had such a choice typically do not involve the choice of *which* new vehicle to buy, but *whether* to buy a new vehicle. The massive switch to unleaded gasoline (and catalytic converters) in the US in the 1970s is one example. With only minor exceptions, consumers could not choose which new car or truck to buy based on their "preference" for leaded fuel or the effectiveness and maintenance cost of their car's emission system. If they preferred leaded gasoline, their only choice was to not buy a new vehicle.

In still other cases, distinct environmental differences, such as emissions of criteria pollutants, were simply never marketed—even in the case of cars versus light trucks. No one—not federal or state governments, not environmental advocacy groups, and certainly not motor vehicle manufacturers—engaged in a systematic effort to educate and inform the public about the fact that light-duty trucks were allowed to be more polluting than were cars for over 30 years (though new rules now require all light duty vehicles in California to meet the same standards, with similar national rules to take effect soon).

The case of airbags is instructive in demonstrating the changing nature of preferences. Interest in safety regulation gradually increased over time, initially aroused by Ralph Nader's 1965 book, *Unsafe at Any Speed*. Support for government intervention eventually evolved into a willingness to pay extra for safety features. This evolution took over 25 years in the US.

The hybrid electric vehicle experience may provide valuable new insights. Preliminary results from a UC Davis study indicates that buyers of the Toyota Prius value low air pollutant emissions equally with the high gas mileage (Kurani and Turrentine, 2004b). Many Prius buyers would have otherwise purchased larger and more expensive vehicles, and have been willing to downsize to the Prius because of its progressive technology. Many buyers speak of wanting to be part of a change, a movement. Who are the hybrid vehicle buyers, how are they making choices, and how representative are they of current and evolving desires and beliefs? These are key questions that remain largely unanswered.

CONCLUSIONS

The era of vehicle regulation is rather short, but rich in experience. Government regulations in California, US and elsewhere have played a large role in the evolution of vehicle technology. Vehicles are now much safer and lower emitting, and consume less fuel (per mile) than several decades ago. Government regulations played a central role in reducing emissions and improving safety. Emissions improvement occurred almost exclusively because of persistent and aggressive government regulation. Market factors and consumer behavior played almost no role. These improvements initially were quite expensive, but government persisted because air quality retained strong public support. Eventually, technical innovation resulted in continuing improvements at little or no extra cost. Current vehicles are cleaner burning than ever and yet the cost of emission control per vehicle is no greater than it was in the early 1980s.

Safety regulation was more complex and protracted. Automakers effectively resisted passive restraints, and especially airbags, for many years. By the time aggressive airbag requirements were adopted in 1991, consumer demand for safety had grown so strong that automakers willingly incorporated airbags well before the statutory deadlines of 1998 for cars and 1999 for light trucks.

Energy regulation has been the most controversial and most complex. The adoption of the Corporate Average Fuel Economy (CAFE) standards in 1975, taking effect in 1978, had a galvanizing effect on the auto industry. Car fuel economy doubled between 1973 and 1985. But fuel prices also soared during this period. CAFE played an important role, but so did fuel prices. Since then car CAFE standards have remained static, and light truck CAFE standards have increased only minimally.

We reviewed one other enlightening experience: the "voluntary" adoption of carbon dioxide (CO_2) emission standards in Europe by automakers. While voluntary, it was made clear that firm enforceable standards would be adopted if the industry failed to attain large CO_2 emission reductions – on the order of 25% per vehicle for a the ten year period from when they were adopted in 1998 until 2008. They are nearly on track to do so. The principal strategy has been to switch from gasoline to diesel engines, which have inherently lower fuel consumption but higher emissions of oxides of nitrogen and particulates. This diesel strategy has been successful because it has been embraced by most of the European countries. The European Union has maintained less stringent emission standards for diesel cars and most countries tax diesel fuel and diesel cars less.

In summary, the success of government regulation depends on some mix of political and consumer support, and consistent market incentives and signals. There is no formula to predict the necessary mix. But the case studies conducted as part of this overall study and summarized here provide the insights and lessons to guide new proposals.

The history of automotive regulation is remarkable in how little it disrupted the industry. Many changes in product mix and industry organization did occur in parallel with the imposition of new government requirements. The market share of light trucks, first minivans and then SUVs, increased dramatically. The industry became much more competitive, with many more large companies from Japan and later Europe gaining considerable market share. And in the past two decades, vehicles have become larger and more powerful. Government regulations clearly played some role in these transitions. The stringent emissions and fuel economy standards in the 1970s gave Japanese automakers the opening to crack the US market, though the rapidly improving and expanding Japanese industry was likely to do so eventually anyway. And the shift to light trucks was encouraged by the less stringent CAFE standards applied to light trucks (and also less stringent safety and emissions standards), providing an incentive to automakers to shift production to minivans and SUVs.

In the end, though, vehicles prices increased much faster over the past decades than did costs associated with regulations, reflecting the considerable improvements in vehicle quality and performance that have taken place over this time. Indeed, we found that even when costly changes were required in a short time – as with the introduction of oxidation and three way catalysts -- the impact on vehicle prices was barely discernible. Vehicle markets have not been perturbed significantly by government regulation in the US, excepting perhaps the perverse effect of CAFE standards encouraging light trucks (pickups, minivans, and SUVs). In Europe, the situation is somewhat different, but in that case it was a not a single regulatory initiative that led to diesel cars, but rather a cluster of coherent policies and rules.

The fact that government regulations did not cause major automotive industry disruptions is due in large part to the many advertising, marketing, financing, and pricing tools available to companies. For instance, even with rising prices, automakers have maintained the affordability of vehicles by providing financial incentives and doubling the length of financing periods. In the short run, automakers can use these tools to adjust to perturbations, whether imposed by government or external market conditions. And in the long term, they respond with technological innovation and product planning changes – building vehicles that last longer, are more reliable, safer, and more environmentally desirable.

The challenge for government regulators as they formulate new regulatory initiatives is to understand shifting market dynamics, anticipate technological innovation, and forecast likely near and long term cost impacts. Easier said than done.

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FINAL REPORT

Contract 02-310
Project No. 008545

Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking –

Effect of Emissions Regulation on Vehicle Attributes, Cost, and Price

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ABSTRACT

This report documents the automotive industry's response to federal regulations of light duty vehicle tailpipe emissions, with the intent of identifying lessons learned that might be applicable to future regulation of greenhouse gas emissions. The focus is on 1975 and 1979-1981, when new standards took effect that led directly to the adoption of costly new emission control equipment. The costs were significant during those time periods – with almost all automakers installing new oxidation catalyst technology in the first time period and three-way catalytic converters in the second. However, prices of new vehicles did not appear to reflect the full costs of emissions control. Other cost and pricing considerations seemed to be even more important. The added compliance costs associated with emissions reduction were just one more factor used by companies in setting prices. Aggregate new car sales were affected only in a minor way by emissions regulations.

EXECUTIVE SUMMARY

The regulation of greenhouse gases from motor vehicles follows a long history of state and federal automotive exhaust emission standards. The automotive industry typically opposes such regulation citing high compliance costs, technological infeasibility, and/or widespread economic impacts. In most cases, the final rules are phased in gradually or the effect on vehicle costs have proved rather modest. Indeed, an analysis of vehicle prices over the past few decades could not detect the effect of emissions or safety regulations (Burke et al 2004; Abeles et al 2004). Thus, we chose to analyze in detail two time periods when emission standards were sharply tightened and were known to require costly new emission control technology. These two periods are 1975 and 1979-1981. In both periods, automakers responded to stricter standards primarily with technological solutions, as opposed to modifications in vehicle attributes such as size or performance. Most manufacturers utilized oxidizing catalysts to meet the 1975 standards, and three-way catalytic converters to meet the latter standards. They also made many other complementary technological changes, including the installation of fuel injection, onboard diagnostic, and computer control technologies.

- **A wide range of costs are associated with emissions regulation compliance.** The total cost of compliance can be separated into the costs initially absorbed by the manufacturer and those passed onto the consumer. Doing so is difficult, though. Types of costs born primarily by automakers include research and development expenditures, capital investments in new tooling equipment, and advertising costs to maintain vehicle sales. One study suggests that manufacturers fully absorb the cost of emissions control equipment immediately after the implementation of more stringent standards and then pass on two-thirds of the costs to consumers the following year. In addition to higher vehicle costs, the changes in the vehicles resulting from new standards may also have different operating costs – such as higher or lower fuel and maintenance costs – and changes in drivability. However, equipment costs comprise the predominant cost.
- **Industry and regulator projections of costs often differ.** When standards were being debated and adopted, it is not surprising that cost projections by government regulators typically turned out to be lower than actual costs, while auto manufacturer projections tended to be higher. In general projections by industry turned out to be more inflated than those by regulators.
- **Changes in emissions control costs were not reflected in changes in vehicle prices.** Actual emission control costs were estimated by several analysts. In all cases, emission control costs per vehicle were estimated to increase with time until 1981, and then diminish. The per-vehicle cost estimates for 1981 vehicles range from roughly $875 to $1350 (US$2002). Average vehicle cost estimates camouflage large variation. Costs varied based on production volume, engine size and type, and many other characteristics. Emission control costs diminished slightly from 1981 to 1994, a period when emission standards were static. These cost reductions are evidence of improvements in the design and manufacturing of emission control systems. Comparison of these emissions control costs with changes in new vehicle price reveals that compliance costs were not passed onto

consumers equally across all vehicles and models. In some years, average vehicle price by vehicle class actually declined, suggesting that any additional costs related to air quality regulations for that year were absorbed either by the manufacturer or purchasers of vehicles in other classes. In other years, vehicle price often increased by an amount greater than the estimated emissions control cost.

- **Vehicle prices depend on a variety of considerations, not just cost.** Clearly many other more important factors were affecting vehicle price. We do not document those other factors, but note that pricing is a highly complex and highly confidential art. We do note that a principal constraint when passing along compliance costs is a desire to moderate price increases, especially after production planning has been finalized. Once factories are tooled and manufacturing processes designed, automakers aim to stick to projected sales volumes. Lower sales volumes results in manufacturing costs—most of which are fixed—to be spread over fewer vehicles, which reduces profits. Increases in vehicle prices may reduce sales, which again affects profits. Automakers employ a number of non-pricing strategies to offset or accommodate cost increases resulting from new standards. They make previously standard equipment optional, eliminate some features, or provide rebates.
- **Changes in emissions regulation were concurrent with periods of economic uncertainty.** Another reason it was not possible for us to document the effect of new regulations on vehicle prices was that many other external forces were at play. Most notable were the oil price shocks that shaped consumer preference and the subsequent regulation of vehicle fuel economy that prompted substantial changes in vehicle design and marketing (and pricing). In addition, there were overlapping periods of economic recessions, high interest rates, and low consumer confidence. In the end, even though the cost impact of emissions regulations was significant during the two case study periods, it is not possible to document the exact impact on prices nor consumer and industry behavior.

1. INTRODUCTION

The regulation of greenhouse gases from motor vehicles follows a long history of state and federal automotive exhaust emission standards. The purpose of this report is to analyze both the auto industry's response to emissions regulations and the subsequent product offered to consumers. By better understanding how auto manufacturers have responded to vehicle regulations in the past, rulemakers will be better prepared to propose greenhouse gas emission standards.

Case Study Approach

Two periods of federal regulation will serve as case studies for industry response to technology-forcing emissions regulations: 1) the introduction of the oxidizing catalyst to meet 1975 standards; and 2) the introduction of the three-way catalyst to meet standards phased-in between 1979 and 1981. The case study approach was selected as the significant changes in emission standards during these periods would minimize any confounding effects, such as variations in fuel prices, vehicle safety regulations, or foreign competition. However, these effects are never completely eliminated, especially for the later case study period when fuel economy standards were introduced. For both of the case studies, the following questions will be addressed:

1. What new or altered technologies were offered by manufacturers?
2. Did increased costs induce manufacturers to change the volume and mix of vehicle types offered for sale?
3. How did manufacturers reflect the cost of new or altered technologies in vehicle prices in the short and long run?
4. To what extent were manufacturers able to raise prices to cover the cost increase associated with new or altered technologies in the short run and long run?
5. How did manufacturers overcome consumer resistance to price increases?

Although the California standards differ from the federal ones, the analysis of industry response has been limited to 49-state version vehicles due to data availability. Thus only the federal regulations will be discussed here. In addition, while light trucks comprise a significant portion of the vehicle fleet at present, lack of data and their limited popularity during the time periods of interest render any analysis inconclusive.

Background on California and Federal emission standards

California has been a pioneer in the regulation of automotive emissions. The state's regulations have generally led to similar federal rules, in part by providing a testing arena for new control technologies. [1] Positive crankcase valve systems were voluntarily installed on all new vehicles sold in California in 1961 and then for all vehicles throughout the country in 1963 to control for blowby emissions. Similarly, exhaust emissions were first regulated in California beginning with model year 1966 vehicles; the standards were established by the California State Health Department at 4.3 grams per mile (g/mi) of unburned hydrocarbons (HC) and 44 g/mi of carbon monoxide (CO) with a durability of 12,000 miles. [2] Federal exhaust emissions controls did not begin until two years later with less stringent requirements. Likewise, California began regulation of evaporative emissions and exhaust nitrogen oxides (NO_x) one year prior to the remaining 49 states.

The federal regulations around which our two case studies revolve have more complex histories. Originally, the 1975 emission standards were set at 0.41 g/mi HC, 3.4 g/mi CO, and 2.0 g/mi NO_x, with NO_x emissions further reduced to 0.4 g/mi the following model year. In both cases, the durability of these standards was set at five years or 50,000 miles (or whichever came first). The levels were intentionally established to exceed the capabilities of existing technologies with the goal of promoting the development of new emissions control devices.[1] As could be expected, automakers contended that such advances were unreasonable to achieve in a cost-effective manner and might even put some companies out of business. [3] Although the original legislation required the Environmental Protection Agency (EPA) to analyze the cost-effectiveness of potential control technologies, Congress explicitly set air quality standards based on health considerations and not costs. [4] Nonetheless, EPA had the authority to delay target dates for a year if the automobile industry was unable to meet the deadline in time with good-faith efforts.

Despite concerns that Chrysler was deliberately stalling, based on evidence that it was spending very little on emissions control research and development (10 to 16 percent that of General Motors and Ford) [5], uncertainty about meeting production targets due to costs prompted the original 1975 standards to be delayed [6]. In their place, interim standards were established for model year 1975 vehicles, halving HC and CO levels to 1.5 g/mi and 15 g/mi, respectively, while NO_x standards remained unchanged. Though these were intended as temporary standards, they still represented significant reductions in allowable emissions levels. The 1977 Clean Air Act Amendments delayed the original standards still further. The original HC requirement of 0.41 g/mi was delayed until 1980 and the CO requirement of 3.4 g/mi was delayed until 1981, as was the NO_x requirement which was also loosened to 1.0 g/mi. Again, these standards represented significant reductions from previous levels, reducing targets by 50 percent or more. However, waivers of the CO standard were available for individual models for the 1981 and 1982 model years of up to 7.0 g/mi. EPA granted these waivers to roughly one-third of all 1981 and 1982 gasoline automobiles. [1] Waivers of the NO_x requirement were also available to small domestic manufacturers such as American Motors for these model years of up to 2.0 g/mi. Besides these waivers, though, the emissions standards applied uniformly to all new vehicles and each vehicle sold that violated the standard would be punishable by a fine of up to $10,000. [5] Despite attempts to revise the Clean Air Act to roll back emission standards for model year 1983 vehicles and beyond, regulations remained virtually unchanged until the 1990 Clean Air Act Amendments.

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[1] Note that AB 1493 does not intend for the Air Resources Board to establish standards that would exceed the capabilities of existing technologies unlike the standards discussed in these case studies.

Table 1.1 California and Federal Exhaust Emission Standards for Passenger Cars (g/mi)

	Federal			California		
Model Year	HC	CO	NOx	HC	CO	NOx
uncontrolled	8.7	90	3.4	8.7	90	3.4
1966				4.3	44	
1967				4.3	44	
1968	4.1	34		4.3	44	
1969	4.1	34		4.3	44	
1970	4.1	34		2.2	23	
1971	4.1	34		2.2	23	
1972	3.0	28		1.5	23	3.0
1973	3.0	28	3.1	1.5	23	3.0
1974	3.0	28	3.1	1.5	23	2.0
1975	1.5	15	3.1	0.9	9	2.0
1976	1.5	15	3.1	0.9	9	2.0
1977	1.5	15	2.0	0.41	9	1.5
1978	1.5	15	2.0	0.41	9	1.5
1979	1.5	15	2.0	0.41	9	1.5
1980	0.41	7.0	2.0	0.41	9	1.0
1981	0.41	3.4	1.0	0.41	7	1.0
1982	0.41	3.4	1.0	0.41	7	0.4
1983	0.41	3.4	1.0	0.41	7	0.4
1984	0.41	3.4	1.0	0.41	7	0.4
1985	0.41	3.4	1.0	0.41	7	0.4
1986	0.41	3.4	1.0	0.41	7	0.4
1987	0.41	3.4	1.0	0.41	7	0.4
1988	0.41	3.4	1.0	0.41	7	0.4
1989	0.41	3.4	1.0	0.41	7	0.4
1990	0.41	3.4	1.0	0.41	7	0.4
1991	0.41	3.4	1.0	0.41	7	0.4
1992	0.41	3.4	1.0	0.41	7	0.4
1993	0.41	3.4	1.0	0.41	7	0.4
1994	0.41	3.4	0.4	0.25†	1.7-3.4‡	0.2-0.4‡
1995	0.41	3.4	0.4	0.231†	1.7-3.4	0.2-0.4
1996	0.41	3.4	0.4	0.225†	1.7-3.4	0.2-0.4
1997	0.41	3.4	0.4	0.202†	1.7-3.4	0.2-0.4
1998	0.41	3.4	0.4	0.157†	1.7-3.4	0.2-0.4
1999	0.41	3.4	0.4	0.113†	1.7-3.4	0.2-0.4
2000	0.41	3.4	0.4	0.073†	1.7-3.4	0.2-0.4
2001	0.075†	1.7-3.4‡	0.2-0.4‡	0.07†	1.7-3.4	0.2-0.4
2002	0.075†	1.7-3.4	0.2-0.4	0.068†	1.7-3.4	0.2-0.4
2003	0.075†	1.7-3.4	0.2-0.4	0.062†	1.7-3.4	0.2-0.4

† Fleet average of Non-methane Organic Gases (not Total Hydrocarbons)
‡ Emission standard varies depending on certification levels TLEV, LEV, or ULEV
SOURCES: U.S. Environmental Protection Agency, California Air Resources Board, California Code of Regulations

2. INDUSTRY RESPONSE TO EMISSIONS REGULATIONS

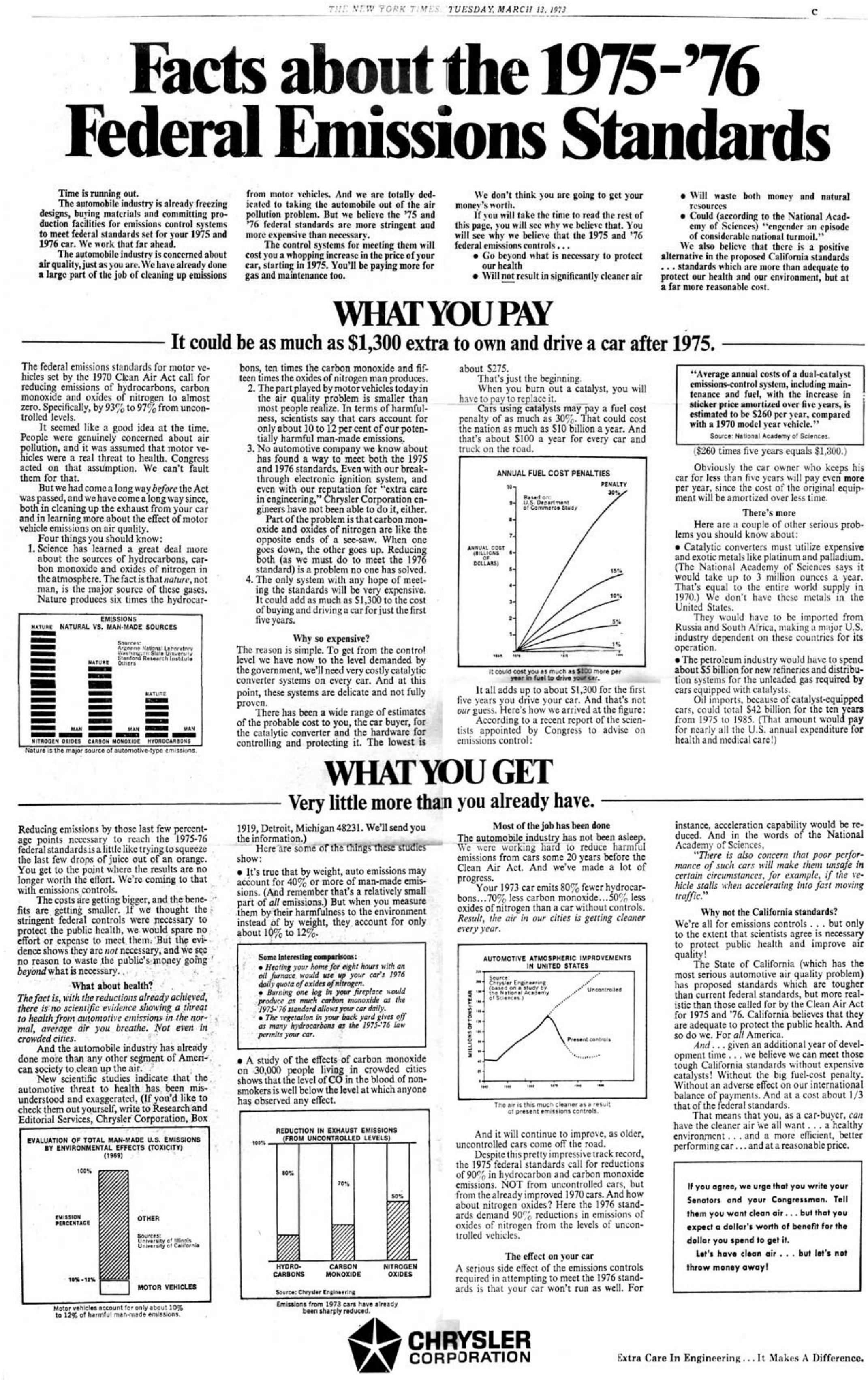
The auto industry's response to emissions regulations can be divided into its actions prior to the standards taking effect and its subsequent compliance actions. Publicly, manufacturers wanted to assure that their opposition to more stringent standards would not damage their public image with consumers. Once the proposed standards became required, each automaker needed to comply with the regulation while still catering to consumer preferences.

Public response to proposed regulations

Not surprisingly, automakers were largely resistant to proposed regulations to increase the stringency of exhaust emissions levels. Ernest Starkman, General Motors' vice president of environmental affairs, testified during a Senate hearing in 1972, "The very stringent levels prescribed [by the proposed 1975 standards]…do not appear to be warranted, either to protect health, prevent plant damage, or to provide aesthetic quality of the air in even the most severely stressed communities of this nation." [7] In general, though, the standards were challenged more on the basis of unreasonable compliance costs (including reduced fuel economy and drivability as well as reduced consumer choice) as opposed to being technologically infeasible or inessential. [8] Of the Big Three companies, Chrysler was the most outspoken against pollution standards due to its smaller size and limited investment capabilities. Figure 2.1 clearly outlines Chrysler's position that such regulation would be costly with little additional direct benefit to consumers. Mobil oil company ran advertisements the same year touting a similar message (Figure 2.2). Though less forthright in its protest, GM was equally concerned that the increased manufacturing costs would do little to increase vehicle quality or a consumer's desire to purchase a vehicle.

An additional issue of contention was the increasing regulation of the industry *per se*. Eugene Cafiero, President of Chrysler stated, "An industry that had very few government restrictions a dozen years ago, now finds almost every action and decision subject to the control of some government agency." [9] The need to constantly redirect research and engineering efforts towards compliance was believed to stifle innovation within the industry. [10]

GM also argued that the abrupt, revolutionary changes required by regulation might disrupt the balance between vehicle supply and demand, and would incur high additional costs. The disruption was relatively greater during the case study period than it would be now because the usual product planning cycle in the industry at that time ranged between five and seven years, depending on the extent of new technology incorporated into the vehicle. [10] (It is now about 2-3 years.) Ford reported at the time that its typical seven-year product cycle required between 44 and 60 months to make significant design changes. [9] Given the regulatory uncertainty, companies faced the prospect of making late changes in factories and vehicle designs, thereby incurring high additional costs. In addition, smaller companies such as Chrysler also felt that the uniform standard unfairly burdened companies with more limited resources and reduced their competitiveness.



THE NEW YORK TIMES, TUESDAY, MARCH 13, 1973 C

Facts about the 1975-'76 Federal Emissions Standards

Time is running out.

The automobile industry is already freezing designs, buying materials and committing production facilities for emissions control systems to meet federal standards set for your 1975 and 1976 car. We work that far ahead.

The automobile industry is concerned about air quality, just as you are. We have already done a large part of the job of cleaning up emissions from motor vehicles. And we are totally dedicated to taking the automobile out of the air pollution problem. But we believe the '75 and '76 federal standards are more stringent and more expensive than necessary.

The control systems for meeting them will cost you a whopping increase in the price of your car, starting in 1975. You'll be paying more for gas and maintenance too.

We don't think you are going to get your money's worth.

If you will take the time to read the rest of this page, you will see why we believe that. You will see why we believe that the 1975 and '76 federal emissions controls . . .

- **Go beyond what is necessary to protect our health**
- **Will not result in significantly cleaner air**
- **Will waste both money and natural resources**
- **Could (according to the National Academy of Sciences) "engender an episode of considerable national turmoil."**

We also believe that there is a positive alternative in the proposed California standards . . . standards which are more than adequate to protect our health and our environment, but at a far more reasonable cost.

WHAT YOU PAY

It could be as much as $1,300 extra to own and drive a car after 1975.

The federal emissions standards for motor vehicles set by the 1970 Clean Air Act call for reducing emissions of hydrocarbons, carbon monoxide and oxides of nitrogen to almost zero. Specifically, by 93% to 97% from uncontrolled levels.

It seemed like a good idea at the time. People were genuinely concerned about air pollution, and it was assumed that motor vehicles were a real threat to health. Congress acted on that assumption. We can't fault them for that.

But we had come a long way *before* the Act was passed, and we have come a long way since, both in cleaning up the exhaust from your car and in learning more about the effect of motor vehicle emissions on air quality.

Four things you should know:

1. Science has learned a great deal more about the sources of hydrocarbons, carbon monoxide and oxides of nitrogen in the atmosphere. The fact is that *nature*, not man, is the major source of these gases. Nature produces six times the hydrocarbons, ten times the carbon monoxide and fifteen times the oxides of nitrogen man produces.
2. The part played by motor vehicles today in the air quality problem is smaller than most people realize. In terms of harmfulness, scientists say that cars account for only about 10 to 12 per cent of our potentially harmful man-made emissions.
3. No automotive company we know about has found a way to meet both the 1975 and 1976 standards. Even with our breakthrough electronic ignition system, and even with our reputation for "extra care in engineering," Chrysler Corporation engineers have not been able to do it, either.

   Part of the problem is that carbon monoxide and oxides of nitrogen are like the opposite ends of a see-saw. When one goes down, the other goes up. Reducing both (as we must do to meet the 1976 standard) is a problem no one has solved.
4. The only system with any hope of meeting the standards will be very expensive. It could add as much as $1,300 to the cost of buying and driving a car for just the first five years.

Nature is the major source of automotive-type emissions.

Why so expensive?

The reason is simple. To get from the control level we have now to the level demanded by the government, we'll need very costly catalytic converter systems on every car. And at this point, these systems are delicate and not fully proven.

There has been a wide range of estimates of the probable cost to you, the car buyer, for the catalytic converter and the hardware for controlling and protecting it. The lowest is about $275.

That's just the beginning.

When you burn out a catalyst, you will have to pay to replace it.

Cars using catalysts may pay a fuel cost penalty of as much as 30%. That could cost the nation as much as $10 billion a year. And that's about $100 a year for every car and truck on the road.

It could cost you as much as $100 more per year in fuel to drive your car.

It all adds up to about $1,300 for the first five years you drive your car. And that's not *our* guess. Here's how we arrived at the figure:

According to a recent report of the scientists appointed by Congress to advise on emissions control:

> **"Average annual costs of a dual-catalyst emissions-control system, including maintenance and fuel, with the increase in sticker price amortized over five years, is estimated to be $260 per year, compared with a 1970 model year vehicle."**
>
> Source: National Academy of Sciences.

($260 times five years equals $1,300.)

Obviously the car owner who keeps his car for **less** than five years will pay even **more** per year, since the cost of the original equipment will be amortized over less time.

There's more

Here are a couple of other serious problems you should know about:

- Catalytic converters must utilize expensive and exotic metals like platinum and palladium. (The National Academy of Sciences says it would take up to 3 million ounces a year. That's equal to the entire world supply in 1970.) We don't have these metals in the United States.

  They would have to be imported from Russia and South Africa, making a major U.S. industry dependent on these countries for its operation.
- **The petroleum industry would have to spend about $5 billion for new refineries and distribution systems for the unleaded gas required by** cars equipped with catalysts.

  Oil imports, because of catalyst-equipped cars, could total $42 billion for the ten years from 1975 to 1985. (That amount would pay for nearly all the U.S. annual expenditure for health and medical care!)

WHAT YOU GET

Very little more than you already have.

Reducing emissions by those last few percentage points necessary to reach the 1975-76 federal standards is a little like trying to squeeze the last few drops of juice out of an orange. You get to the point where the results are no longer worth the effort. We're coming to that with emissions controls.

The costs are getting bigger, and the benefits are getting smaller. If we thought the stringent federal controls were necessary to protect the public health, we would spare no effort or expense to meet them. But the evidence shows they are *not* necessary, and we see no reason to waste the public's money going *beyond* what is necessary.

What about health?

The fact is, with the reductions already achieved, there is no scientific evidence showing a threat to health from automotive emissions in the normal, average air you breathe. Not even in crowded cities.

And the automobile industry has already done more than any other segment of American society to clean up the air.

New scientific studies indicate that the automotive threat to health has been misunderstood and exaggerated. (If you'd like to check them out yourself, write to Research and Editorial Services, Chrysler Corporation, Box 1919, Detroit, Michigan 48231. We'll send you the information.)

Motor vehicles account for only about 10% to 12% of harmful man-made emissions.

Here are some of the things these studies show:

- It's true that by weight, auto emissions may account for 40% or more of man-made emissions. (And remember that's a relatively small part of *all* emissions.) But when you measure them by their harmfulness to the environment instead of by weight, they account for only about 10% to 12%.

> **Some interesting comparisons:**
>
> - *Heating your home for eight hours with an oil furnace would use up your car's 1976 daily quota of oxides of nitrogen.*
> - *Burning one log in your fireplace would produce as much carbon monoxide as the 1975-'76 standard allows your car daily.*
> - *The vegetation in your back yard gives off as many hydrocarbons as the 1975-'76 law permits your car.*

- A study of the effects of carbon monoxide on 30,000 people living in crowded cities shows that the level of CO in the blood of non-smokers is well below the level at which anyone has observed any effect.

Emissions from 1973 cars have already been sharply reduced.

Most of the job has been done

The automobile industry has not been asleep. We were working hard to reduce harmful emissions from cars some 20 years before the Clean Air Act. And we've made a lot of progress.

Your 1973 car emits 80% fewer hydrocarbons...70% less carbon monoxide...50% less oxides of nitrogen than a car without controls. *Result, the air in our cities is getting cleaner every year.*

The air is this much cleaner as a result of present emissions controls.

And it will continue to improve, as older, uncontrolled cars come off the road.

Despite this pretty impressive track record, the 1975 federal standards call for reductions of 90% in hydrocarbon and carbon monoxide emissions. NOT from uncontrolled cars, but from the already improved 1970 cars. And how about nitrogen oxides? Here the 1976 standards demand 90% reductions in emissions of oxides of nitrogen from the levels of uncontrolled vehicles.

The effect on your car

A serious side effect of the emissions controls required in attempting to meet the 1976 standards is that your car won't run as well. For instance, acceleration capability would be reduced. And in the words of the National Academy of Sciences,

"There is also concern that poor performance of such cars will make them unsafe in certain circumstances, for example, if the vehicle stalls when accelerating into fast moving traffic."

Why not the California standards?

We're all for emissions controls . . . but only to the extent that scientists agree is necessary to protect public health and improve air quality!

The State of California (which has the most serious automotive air quality problem) has proposed standards which are tougher than current federal standards, but more realistic than those called for by the Clean Air Act for 1975 and '76. California believes that they are adequate to protect the public health. And so do we. For *all* America.

And . . . given an additional year of development time . . . we believe we can meet those tough California standards without expensive catalysts! Without the big fuel-cost penalty. Without an adverse effect on our international balance of payments. And at a cost about 1/3 that of the federal standards.

That means that you, as a car-buyer, *can* have the cleaner air we all want . . . a healthy environment . . . and a more efficient, better performing car . . . and at a reasonable price.

> **If you agree, we urge that you write your Senators and your Congressman. Tell them you want clean air . . . but that you expect a dollar's worth of benefit for the dollar you spend to get it.**
>
> **Let's have clean air . . . but let's not throw money away!**

CHRYSLER CORPORATION

Extra Care In Engineering . . . It Makes A Difference.

Figure 2.1. Full page advertisement published in the New York Times by Chrysler Corporation (1973)

©1973 Mobil Oil Corporation

The $66 billion mistake

In 1970, Congress passed a series of amendments to the Clean Air Act. One of them said that all cars sold in the U.S. after 1974 must be near-zero polluters.

It sounded fine. Near-perfect emission control seemed not only desirable, but imperative. At that time, people widely assumed that the air was getting steadily dirtier because of the automobile. Most people also assumed that industry could solve any technical problems that might be encountered—and at a reasonable cost.

The goal has proved elusive. Despite the expenditure of hundreds of millions of dollars, and uncounted hours of research and development time, no control system that meets all the requirements of the federal standards has yet been proved.

Bad news? Not necessarily. Today both industry and government have the benefit of research results and other information that were simply not available when Congress passed its amendment in 1970.

Today we know that:

• Total air pollution from cars has already been rolled back to the level of about 1960, and is continuing to drop.

• Cars that met the federal standards would probably be poor performers and gasoline-guzzlers. They also could need costlier maintenance than today's cars.

• A less restrictive level of controls on automotive emissions would do very nearly as much for air quality as the federal standards would.

• Meeting the federal standards could cost $100 billion over the ten years starting in 1976; meeting the less restrictive standards could cost $34 billion. The difference could be a $66 billion mistake.

If not perfection, what?

The only way to completely eliminate auto pollution would be to do away with the auto itself. Since this would be neither practical nor desirable, what percentage reduction of emissions should we aim at? By what date? And at what cost?

The goal should be to make the auto as small a contributor to air pollution as technology allows—but without incurring exorbitant costs for dubious results. Since technology does not stand still, this would be a moving goal. Today's impractical dream often can be tomorrow's reality.

Today's reality in automotive pollution control is, in fact, yesterday's dream: As Chart 1 indicates, emissions of hydrocarbons, carbon monoxide, and nitrogen oxides have been drastically reduced from the days (not long ago) when exhaust emissions were uncontrolled. Changes in engine design plus pollution-control devices have reduced emissions by 1973-model cars an average of 66%.

This is quite an achievement. And as a result, total air pollution from automobiles has been declining in the United States since 1968, and is now down to the levels of about 1960. It would continue to decline for several more years even if no further controls were imposed, as old cars with few if any controls are scrapped.

So. How much further should we go? And by when?

California has a better way

The Air Resources Board of the State of California (and who has more auto-related air-pollution problems, or has had more experience dealing with them?) has proposed automotive emission-control levels based on air-quality standards calculated to restore the atmosphere of Los Angeles to its quality of the early 1940s. California proposes to cut the three principal auto emissions by an average of 83%.

Mobil has been engaged in intensive auto-emission research for several years. We were the co-founder (with Ford Motor Company) of the Inter-Industry Emission Control program, or IIEC, which is probably the largest private cooperative research program of its kind in the world. So Mobil knows something about the problem, too. We believe the California standards can be achieved with in-sight technology, at a reasonable cost.

The California standards are similar to those proposed by the federal government's own Department of Health, Education and Welfare in 1970.

The HEW standards were not accepted. Instead, Congress voted for the last bar on Chart 1. The Clean Air Act now mandates that the three emissions be reduced by 97%, 96%, and 93%—for an average of 95%.

These levels must be reached by 1975 for hydrocarbons and carbon monoxide, and by 1976 for oxides of nitrogen, unless the federal government grants an extension.

AUTO EMISSION REDUCTIONS BELOW PRE-CONTROL LEVELS

	Hydro-Carbons	Carbon Monoxide	Oxides of Nitrogen
1973 Cars	80%	69%	50%
California	94	81	75
Federal	97	96	93

A 95% reduction in emissions may not seem much more difficult to achieve than an 83% reduction. But did you ever try to wring the last drop of water out of a wet towel? One good twist and most of the water flows out. Another hard twist and a little more dribbles out. But now the law of diminishing returns sets in. It's just plain impossible to wring the towel dry, and not worth the effort.

Similarly, the last few percentage points of automotive emission control are far costlier and far more difficult to achieve than the first 80 to 85 points.

Almost every day, we read in the newspapers about some sensational new device that will cut auto pollution virtually to zero. Mobil technical people have investigated many of these devices. A few offer exciting possibilities, given time for development. But none has yet demonstrated it will be ready to meet federal requirements in the short time remaining.

Sneak preview: your '76-model car

Mobil's analysis of current technology indicates that if federal-level cars could be built, their emission-control systems would be so complicated and demanding that the cars could:

• Cost several hundred dollars more than present cars.

• Consume considerably more gasoline than today's cars.

• Need frequent and costly tune-ups and maintenance to keep their emission-control systems operating.

• Present difficult driveability problems, with a tendency to stutter, stammer, and stall—which could become a safety hazard.

On the other hand, cars built to the California standards will cost less to buy and to operate, and will perform better, than cars built to the federal standards.

Mobil sells gasoline, but we have no desire to see our products wasted. Cars built to the federal standards could consume as much as 15% more gasoline per mile than cars built to the California standards. That 15% would require refining an extra 30 million barrels of crude oil in 1976, and an extra 150 million barrels a year by 1980. All that crude oil would have to be imported, with a substantial—and unnecessary—drain on our country's balance of payments.

Catalysts would be necessary to meet the federal standards. From 1975 through 1980 the auto industry apparently will have to import some 10,000,000 ounces of platinum and some other noble metals for catalysts—for a cumulative balance-of-payments drain of at least $1,300,000,000, based on present prices.

The motorist also would need to replace the catalyst as it deteriorated—perhaps every 20,000 or 25,000 miles.

About the safety aspect. Dr. Arie J. Haagen-Smit, chairman of the California Air Resources Board, offers this chilling caution: "The driveability problems such cars will present may become clear to a motorist only at the worst possible time—when he comes up the ramp to swing into 70-mile-an-hour freeway traffic. A stumble then may be the last mistake he'll ever make."

The gap between the emission reductions that could be achieved by the California and the federal standards would be very small, for several years at least.

It could turn out to be very small indeed, because the complicated systems needed to meet the federal standards could break down more easily—and if they did, the car's emission-control system could become completely ineffective.

Up the Matterhorn

Which brings us to Chart 2. The one with a curve that looks like the southeastern slope of the Matterhorn.

Control equipment to meet the 1973 standards adds about $65 to $100 to the cost of a new car. Not excessive, considering how far the cars have come in reducing harmful emissions.

The price curve turns up to meet the California standards—to a range of $175 to $300 per car for the control equipment. Perhaps still not too expensive, considering the extra gains in pollution reduction.

But to reach the federal standards that are now the law for 1975 and 1976 models, the cost curve heads almost straight up. These systems could cost $500 to $600 a car—and maybe more. We can't determine the exact cost, since systems to meet the 1976 standards have not been proved.

These are just the initial costs of the emission-control systems. Add the extra maintenance, and throw in the additional gasoline, and the grand total for meeting the federal standards comes to $100 billion over the decade starting in 1976.

Add the same expenses for the California standards, and the grand total is $34 billion. (All these figures are Mobil engineers' estimates, expressed in today's dollars.)

Our calculations do not include a cost for the special kind of gasoline that would be needed to meet the federal standards.

Clean air and public transportation

Is there a better way to spend all or part of $66 billion to reduce total automotive air pollution?

There is indeed. Public transportation. Public transportation clean enough, safe enough, fast enough, and priced attractively enough to induce Americans to use their automobiles less and public transportation more.

For $66 billion we could build 44 public transportation systems such as BART (Bay Area Rapid Transit system) in San Francisco. Or 22 subway systems like the Metro now under construction in Washington, D.C. If the country finds it doesn't want or need that many subways or BART-type systems, there are other forms of public transportation to keep in mind. Express bus lanes on freeways are one of the most efficient of all ways to move people. Also, as everyone knows, America's commuter and longer-haul railroads urgently need modernizing.

As we said in October, 1970, "Providing for our future transportation needs will require very large expenditures. We believe there's an urgent need for legislators to re-examine the procedures used to generate and expend transportation revenues."

To achieve this, we said in January, 1972, "Congress should enact a National Master Transportation Program."

What would $66,000,000,000 buy?

The program Mobil outlines in this report could save the American consumer $66 billion over ten years. That's far too much money for most of us to comprehend. But here are a few things $66 billion could do:

• Build the water-treatment plants needed for all the country's household, municipal, and industrial sewage and waste water—and maintain those facilities for more than five years.

• Nearly pay the annual U.S. expenditures for all health and medical care ($67 billion in 1970).

• More than finance all new private and public housing construction in this country for two years (1970 total: $30 billion).

• Almost pay the total cost of all types of education in the U.S., at all levels, for a year (1970 total: $69 billion).

• Buy various combinations of subways, BART systems, commuter trains, longer-haul railroads, and express lanes for buses on freeways.

More and better public transportation can go a long way toward several desirable objectives: Less air pollution. Less waste of gasoline. Less pressure on the U.S. balance of payments as our imports of oil inevitably rise. And maybe less emotional strain on motorists and fewer accidents.

The critical fourth dimension

Companies in various industries are developing emission-control systems and testing them for durability and economy. Some of these systems offer exciting possibilities for reducing emissions to very low levels at a reasonable cost. But the most critical element is time—time to test various devices and systems for thousands of miles and to engineer the systems for mass production.

The dilemma as we see it is that the federal government has legislated results by a specified date without knowing how or at what cost they could be achieved, if at all. Here is a program we believe will get the country off the horns of this dilemma:

1 The Environmental Protection Agency should grant a one-year extension of the present federal standards, as provided in the Clean Air Act.

2 Congress should re-examine that act. We hope a thorough analysis will convince the members to amend the act to mandate emission levels closer to those California proposed.

3 The federal government should continue to monitor air quality levels, and to sponsor research into the impact of emissions from all sources on health and well-being. If car-population trends or other data should indicate a future need for further reductions in auto emissions, new standards should be set.

4 The automotive, petroleum, and related industries should be required to continue at a high level their research and development programs on emission-control systems to reduce costs and increase efficiency.

5 The Congress should proceed forthwith to enact a National Master Transportation Program to enable people (and goods) to move fast, safely, comfortably, and at reasonable cost on a first-class system of public transportation adequately supported by Congressional appropriations.

Under such a program, motorists could drive better-performing, less expensive, and safer cars. A substantial drain on the U.S. balance of payments, for crude oil and platinum, would be avoided. A vital and scarce natural resource—petroleum—would be conserved. And the advance of technology would enable auto makers to meet even stricter control standards—if they were found necessary at some future date—with durable, trouble-free, and reasonably economic systems.

Not to mention avoiding a $66 billion mistake.

Mobil®

This advertisement appeared in The Chicago *Tribune*, The Los Angeles *Times*, The New York *Times*, *The Wall Street Journal*, and The Washington *Post*.

Figure 2.2. Full page advertisement published in multiple national newspapers by Mobil Corporation (1973)

What new or altered technologies were offered by manufacturers?

Automakers had a number of options to comply with new air quality standards. Arguably, one strategy for meeting emissions targets was to reduce vehicle weight, which would inherently reduce the amount of emissions control necessary, especially NO_x. According to White (1982), though, "very little downsizing occurred because of the

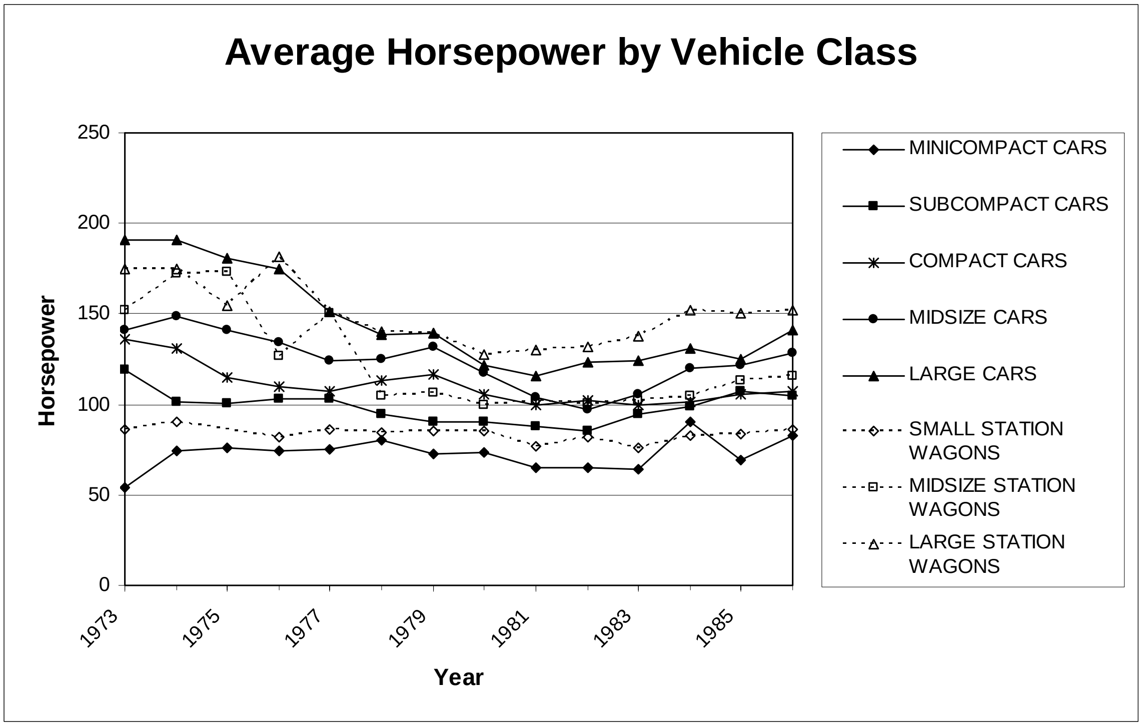


Figure 2.3 Average Horsepower by Vehicle Class

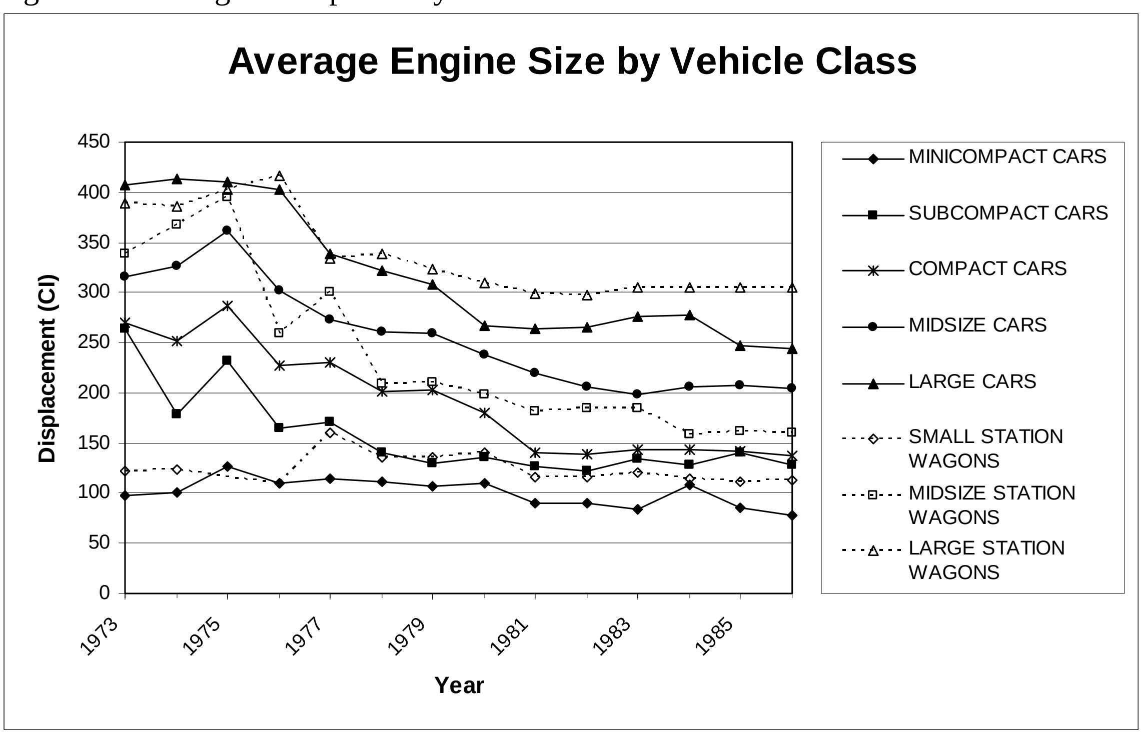


Figure 2.4 Average Engine Size by Vehicle Class

regulations; the American manufacturers appeared to be quite determined to meet he requirements through changes in technology rather than changes in size.” [5]

Analysis of the CARBITS vehicle attribute database also reveals minimal impacts on performance indicators such as horsepower and engine displacement. (See Appendix A for description of CARBITS database.) As shown in Figure 2.3 horsepower dropped more substantially for larger vehicles during early regulation; for smaller vehicles horsepower remained fairly stable, perhaps aided by larger engines as seen in Figure 2.4. Over the second period of more stringent emissions requirements, engine size dropped uniformly while horsepower remained fairly stable, suggesting that engines became more efficient per displacement volume.

While modifications to vehicles such as weight and size reductions were potential strategies to help meet new emissions requirements, technological changes were also necessary. Technologies considered for meeting the 1975 standards included: the modified conventional gasoline engine with an oxidation catalyst, the carbureted stratified-charge engine, the Wankel engine with an exhaust thermal reactor, and the diesel engine. [11] Despite some concerns about platinum supplies, the catalytic converter was viewed as the most promising technology as it required no major changes in powertrain technologies and the other strategies appeared riskier since they all increased NOx emissions, and more stringent NO_x standard were forthcoming. The decision to install catalytic converters was also partly influenced by consumer preferences for high fuel economy following the oil embargo; vehicles could meet emission requirements with after-treatment devices other than catalysts but only at the expense of poor fuel economy. [12] Thus, by the 1975 model year, only 15% of vehicles were not equipped with catalysts. [6] By model year 1977, this figure dropped to only 10% of vehicles. [13] The remaining vehicles complied by using rotary or stratified-charge engines. These vehicles were typically produced by small foreign manufacturers (Mazda, the rotary engine, and Honda the stratified charge).

Table 2.1 Compliance Technologies for 1975-1981

Manufacturer	**Compliance Technologies**
AMC	Oxidation catalyst, three-way catalyst
Chrysler	Electronic lean-burn system, oxidation catalyst, three-way catalyst
Ford	Oxidation catalyst, three-way catalyst
GM	Oxidation catalyst, three-way catalyst
Toyota	i.) three way catalyst (>2000 cc engines) ii.) lean air-fuel mixtures and oxidation catalyst (1500-1800 cc engine) iii.) oxidation catalyst (1300 cc engine)
Nissan	i.) three way catalyst (large models) ii.) fast-burn engine (NAPS-Z) (medium-range models) iii.) improved oxidation catalyst (<1500 cc engine)
Honda	CVCC engine with thermal reactor
Volkswagen	Oxidation catalyst, three-way catalyst, diesel engine

Sources: [9, 10]

Additional technologies were considered to comply with the later more stringent NO_x requirement. These included: the modified conventional engine with dual catalysts and a thermal reactor, the modified conventional engine with a reduction catalyst and two thermal reactors, the modified conventional engine with a three-way catalyst and electronic fuel injection, and the stratified-charge engine with fuel injection and an oxidation catalyst. [11] Although reports were initially pessimistic about the feasibility and cost-effectiveness of these technologies, the three-way catalyst—which oxidizes HC and CO while also reducing NO_x—ultimately proved to be an effective and reliable technology. [14]

Although the larger manufacturers could afford to explore multiple alternatives, in the end most settled on similar compliance strategies. (See Table 2.1) Those companies that did diverge, though, were not terminally disadvantaged by their decision. Both Chrysler and Honda were skeptical about the effectiveness of catalytic converters. Chrysler initially believed them to be unreliable and a potential fire hazard from their excessive heat buildup. Thus in 1975 and 1976 Chrysler relied on controlling the air-fuel ratio using an electronic lean-burn system. Chrysler finally installed catalytic converters in 1977 when the electronic lean-burn system proved insufficient to meet stricter standards. Honda's concern regarding catalytic converters revolved around the uncertainty of the products from the chemical reactions, the durability of the device, and doubt about platinum availability and reclamation. In addition, both Toyota and Nissan scaled their strategies based on engine sizes. Larger vehicles required three-way catalysts since the increased vehicle weight complicated the use of lean-burn engines while smaller vehicles only required oxidation catalysts to comply with 1977 and 1978 standards. [10]

However, the installation of emissions control devices alone was not sufficient to comply with both sets of new standards. In addition to engine system modifications, strategies such as more precise carburetion and spark timing, higher compression ratios, and exhaust gas recirculation were also necessary. [15] Fuel injection also appeared in a large number of model year 1975 vehicles which had previously not been fuel-injected. In later years, as fuel injection technology improved, it was combined with computer controls and sensors to improve the performance and reduce the cost of emission control. [13] Future developments in air meters for injection systems also contributed to maintaining precise air-fuel ratios to control emissions. [2] Additionally, the installation of the three-way catalyst depended on the development of more sophisticated electronic control devices as well as elimination of lead in gasoline to prevent significant deterioration of the catalyst.

It is also important to note that emissions control devices produce feedbacks in the design of the vehicle. For example, the addition of control technologies increases the vehicle weight as well as requires auxiliary devices, such as air pumps. These additional parts may require other maintenance or repair costs. The reverse is also true. The introduction of unleaded gasoline increases the life of the exhaust system and spark plugs, thus reducing maintenance costs, while the use of computer controls allows better combustion control and higher energy efficiency. [15]

Did manufacturers change the volume and mix of vehicles types offered for sale?

Although in general the attributes of the vehicles themselves may have remained relatively stable, the mix of vehicle types shifted during the late 1970's. Figure 2.7

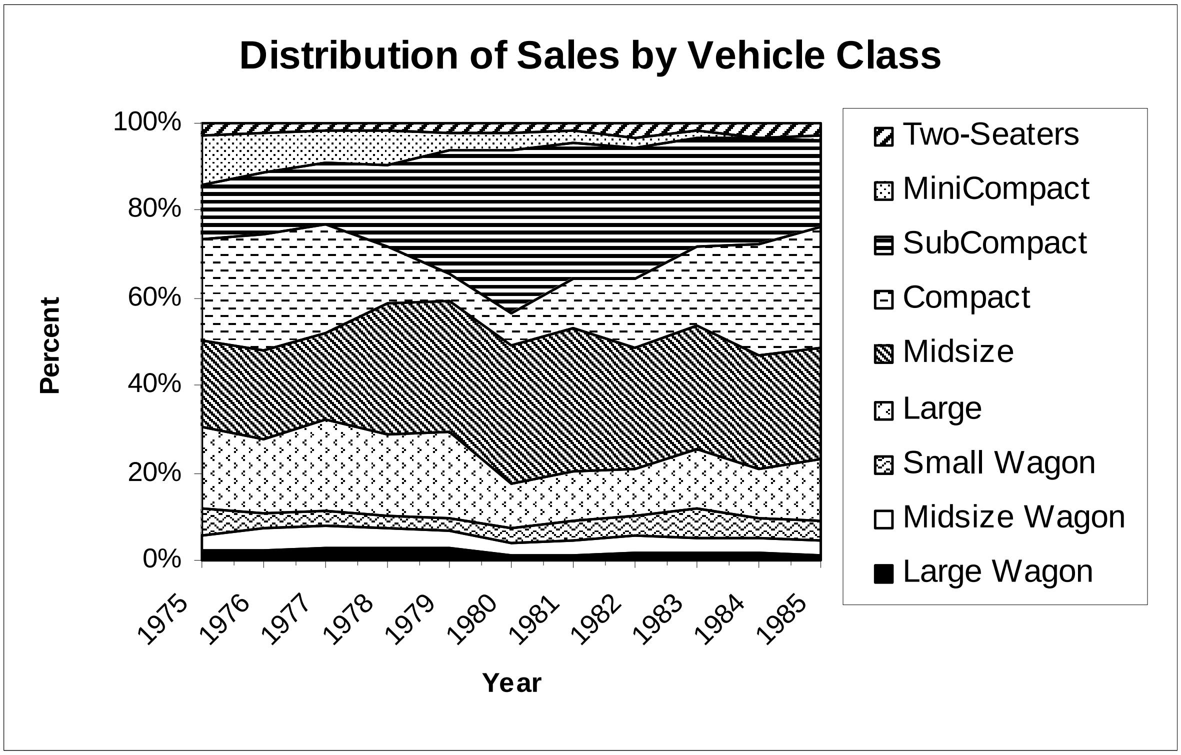


Figure 2.5 Distribution of Sales by Vehicle Class
SOURCE: Hellman, K.H. and R.M. Heavenrich, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2004. 2004, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. EPA420-R-04-001.

illustrates the number of vehicles sold within each vehicle class. There is significant yearly variation among classes. In 1980 subcompact sales increased dramatically while sales of large cars simultaneously plunged. Shortly after, compact sales grew and reduced the share of subcompact vehicles. These trends demonstrate the industry's ability to modify production volumes within rather short time frames. In only three years during the late 1970's, production of small cars rose from less than a million to approximately 4.5 million. [16]

However, it is difficult to distinguish how much of this shift can be attributed to the auto industry attempting to meet stricter regulations and how much was motivated by fuel economy. [17] In addition, the introduction of CAFE standards complicated manufacturers' decisions about fleet mix. Small cars, while helping to achieve CAFE requirements, were less profitable than larger cars. John Deaver, manager of Ford's economics department, affirmed that "product mix decisions are now determined by the number of large and medium-sized cars the company believes it can sell, and then by the number of small cars it needs to produce/sell in order to meet CAFE requirements." [as cited in 10]

3. COSTS ASSOCIATED WITH EMISSIONS REGULATIONS

New technologies almost always incur additional costs. Whether these additional costs are absorbed by the auto manufacturers or passed onto consumers is somewhat unclear. First, it is important to distinguish between cost and price. Price is what consumers pay. The actual cost is usually less, since a company needs to make a profit. Determining the costs of emissions control can be a fairly complex process as more than just material costs are involved.

A thorough calculation of costs incurred by manufacturers would include the costs of tooling new machinery to accommodate the new control devices, as well as the research and development expenditures invested to develop the devices and to reengineer vehicles to comply with more stringent regulations. Note in Figures 3.1a and b that the larger expenditures tend to occur prior to new regulations taking effect. Both Ford and GM exceeded their typical R&D expenditures of 3 percent of total corporate revenues in 1973 and 1974 to comply with new regulations. [9] However, R&D expenditures cannot be solely attributed to emissions controls. For example, rise in investment spending in 1977 and 1978 is largely due to the reengineering of smaller vehicles with front-wheel drive to meet new fuel economy standards. [18]

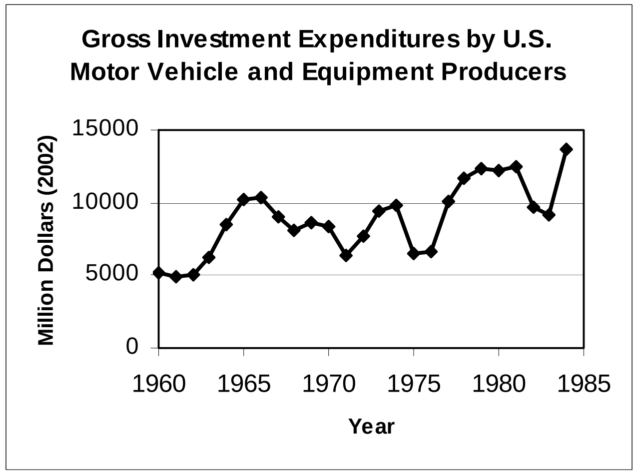


Figure 3.1a

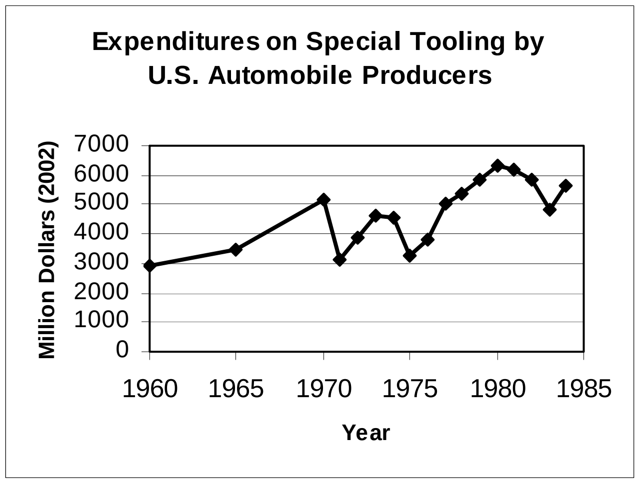


Figure 3.1b
SOURCE: [18]

In addition to the difficulties of accounting for all costs, further complexities arise as vehicles are designed as integrated systems and a single vehicle part may serve multiple functions. Thus, accurately apportioning the costs of emissions control systems to only actual emissions control can be difficult. For example, Bresnahan and Yao found that increases in capital costs resulting from regulation were partially offset by corresponding increases in quality related to developments in emissions technology. Technologies such as electronic controls and fuel injection significantly increase vehicle quality while simultaneously contributing to emissions reductions. [13]

Costs are also difficult to calculate as they vary depending on vehicle weight, engine design, and engine calibration. [6] Furthermore, costs will differ by manufacturer. For example, American Motor Company's (AMC) fleet was heavily dominated by smaller vehicles, thus reducing the need to make significant modifications to meet emission standards. In addition, as a smaller firm AMC tended to depend on outside suppliers for new technologies, allowing them to forego major research and development investments. With mandatory technology, though, AMC lost some of its negotiating powers and usually had to accept whatever price suppliers requested. In contrast, GM as the largest manufacturer enjoyed much more control in its product development.

Emissions control system cost estimates

A number of cost estimates were made prior to and during the regulatory process to assess the feasibility and cost-effectiveness of more stringent emissions standards. These estimates are difficult to compare, though, as they reflect different vehicle configurations and may also include costs besides just hardware (such as maintenance costs or fuel penalties). In addition, many estimates are presented as incremental costs from previous (or sometimes ambiguous) years, which make comparisons impossible unless the baseline years are identical. For example, Grad et al. estimated the cost of compliance with the 1975 interim standards using various engine configurations with and without catalysts ranging from $207 to $352 (2002 dollars), presenting the costs as the increase in sticker price over the 1974 model equivalent. [19] *Automotive News Annual 1978* calculated $435 (2002 dollars) as the price increase since 1968 for emissions control equipment in 1978 cars. [as cited in 10] One widely cited estimate of $860 (not specified if this is real or current dollars) reflects the cost to consumers for vehicles complying with the original 1976 standard over the 1970 vehicle cost at a durability of 85,000 miles. This estimate includes the cost of dual HC/CO, NO_x catalytic converters, a low-grade rich thermal reactor, and exhaust gas recirculation. [15] Other studies simply

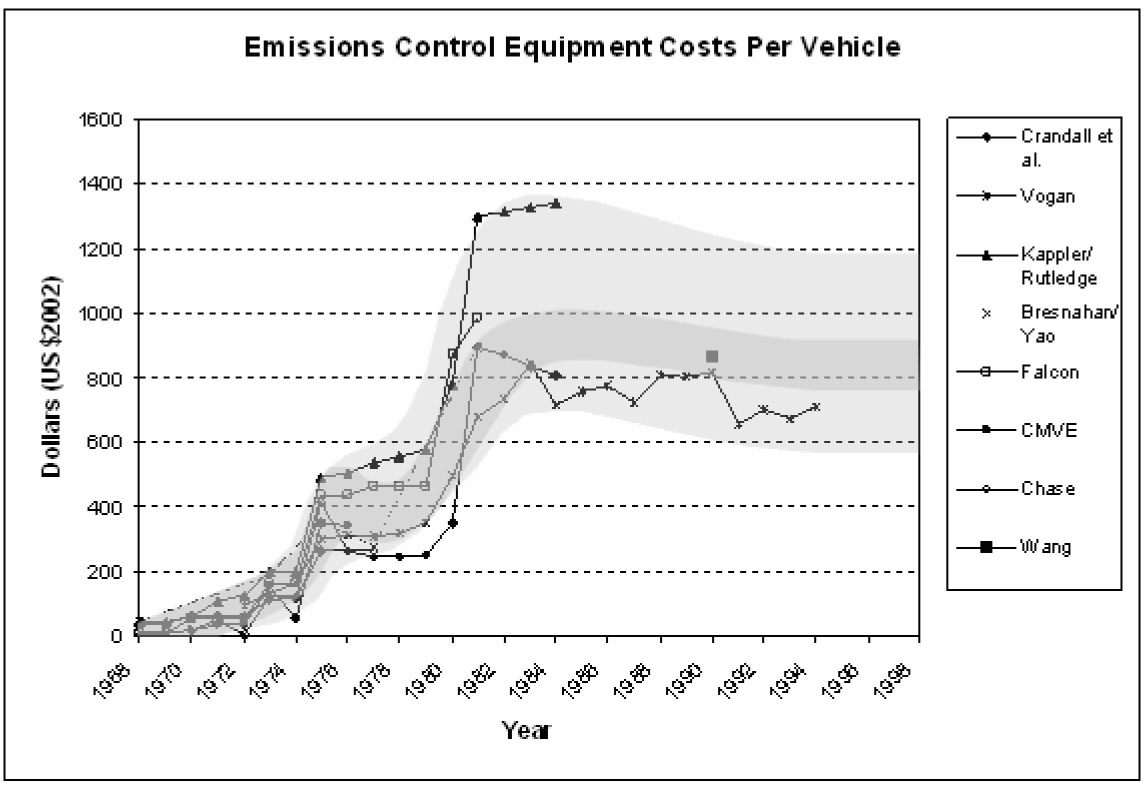


Figure 3.2 Emissions Control Equipment Costs per Vehicle

report costs per new vehicle for control hardware without reference to a base year. These types of isolated cost estimates are less informative than longitudinal analyses of compliance costs.

There are a few studies with estimates of equipment costs to consumers through time, though. (Figure 3.2) These assessments, while somewhat varied also show remarkable similarities, especially until 1981. The earliest two studies projected compliance costs before the regulations took effect. [20, 21] The remaining studies all performed their analyses retrospectively. [12, 13, 18, 22-24] All of these estimates peak in 1975 and then again in 1981. During this second peak, Kappler and Rutledge estimated that consumer spending on catalytic devices increased by 21 percent in 1980 (constant dollars) and then by 18 percent the next year, mostly attributable to the popularity of three-way catalysts. Meanwhile spending on noncatalytic equipment rose by 23 percent in 1980 and then by 51 percent the following year, largely due to the installation of expensive electronic controls. [12]

One potential drawback of these estimates is that they reflect the average for all vehicles and do not make any distinctions for the various vehicle models or producers. Wang et al. used a parts-pricing approach on model year 1990 vehicles to calculate emissions control costs. They found that compliance costs do indeed vary widely depending on vehicle size and manufacturer ($254-$1684 adjusted to 2002 dollars). [24] The higher costs were for luxury vehicles from Europe. The differences among size classes were not as extreme, with emission control costs averaging $504 for compact cars (2002 dollars) and $586 for large cars (2002 dollars), not weighted by sales.

Whether a similar distribution in costs across vehicle sizes exists for earlier model years, particularly when technologies were still maturing, is unclear. Overall, Wang et al. estimated the average cost to consumers for 1990 vehicles to be $862 (2002 dollars). However, this value includes an apportionment of all components for emissions control, even those that serve multiple functions, such as fuel injection and electronic controls (e.g., one-fourth of the cost of fuel injection was apportioned to emission control). Accounting for only equipment dedicated fully to emissions control, the cost was $627 per vehicle (2002 dollars).

One note of caution when analyzing compliance costs is that some estimates include both the hardware costs as well as the additional operating costs. Consumers may be expected to incur costs through increased fuel consumption, fuel prices (for unleaded gasoline) or maintenance and repair requirements. Thus, total costs associated with emissions regulation can significantly exceed the cost of equipment alone. In some cases, though, consumers may experience cost savings through secondary benefits that reduce maintenance needs or fuel consumption. For instance, the installation of the catalytic converter to comply with interim 1975 standards resulted in a net consumer savings of $65 [14] to $310 [13] depending on the source of the estimate.

Variations in estimates by source

Cost estimates of emissions controls prior to the regulation taking effect often vary depending on the source of the projection. Government agencies assigned the responsibility of evaluating the cost-effectiveness of a standard may feel pressured to project optimistic estimates while industry sources have an incentive to project pessimistic estimates in hopes of derailing the regulation. For example, EPA estimated that compliance with the 1981 emission standards would cost \$388 (in 2002 dollars) more than the 1979 vehicle. In contrast, Ford projected a cost of \$596 while GM estimated \$529 (both 2002 dollars) [1] As another examples, cumulative costs through 1976 were estimated by EPA to be \$837 (in 2002 dollars) while industry estimates ranged from \$761 (-9 percent different from EPA's) to \$1093 (+31 percent). [11] Even a committee of the National Academy of Sciences estimated cumulative costs for emissions controls through 1974 to be 39 percent higher than EPA projections. [11]

However, few studies have been conducted to assess the accuracy of projected emissions costs to actual costs, and even fewer of those have been specifically on vehicle exhaust emissions standards. [25] In part, these types of analyses are difficult to conduct not just because of the complicated nature of estimating costs as discussed in previous sections, but also because actual compliance costs are generally regarded as proprietary information by auto manufacturers and therefore not publicly available for comparison. One study does exist by Anderson and Sherwood (2002) that compares projected and actual costs of reformulated gasoline programs. According to their findings, industry projections of fuel price changes prior to the program taking effect substantially exceeded the actual price increase, in some cases two to four times higher. [25] The only other comparison was performed by EPA, specifically assessing vehicle emissions control costs. This study showed that EPA's estimates tended to range between plus or minus 20 percent of actual costs, while estimates from manufacturers ranged from minus 50 percent to as much as 140 percent above the actual costs. [1] Thus, industry estimates tend to have much wider error ranges.

Changes in compliance costs over time

When any technology matures, costs can be expected to fall as manufacturers learn to design and manufacture the product better, and as increased production volumes create economies of scale. Failure to consider these manufacturing improvements would lead to overestimates of emissions compliance costs. Bresnahan and Yao found compliance costs to be extremely high immediately following the initial regulation as manufacturers are given limited time to come into compliance. During this period, control costs are high because tooling costs for transitional technologies are spread over a short time span. The costs then fall with the introduction of new improved and longer-lasting technology. [13] Costs may also fall with time because a change in vehicle design only needs to be developed once but can be used again in following years at no additional cost. [10]

Quantifying the changes in compliance costs due to these factors is complicated. The Office of Science and Technology's report on cumulative regulatory effects on automotive transportation costs uses the following equation to calculate learning curves for vehicle production, defined as "increased production efficiency, which will reduce the initial investment costs as experience is gained in production":

$$\mathbf{C = investment\ cost/vehicle = 350 - 110\,(1 - e^{-0.33t})} \text{ (in 1970 dollars),}$$

where t represents the time elapsed since 1976 and 350 represents the initial per vehicle investment cost. Based on this formula, production costs would stabilize at \$633 (2002 dollars) after 1985. [26] Comparison with Figure 3.2 shows that this value is slightly below the actual costs, though costs per vehicle do appear to have stabilized.

The effects of economies of scale on costs are difficult to determine for the entire emissions control system as the configuration of these systems is frequently changing. Ideally, analysis could be performed on individual components of emissions control systems, such as catalytic converters or exhaust gas recirculation systems. However, cost estimates of these components are limited and therefore cannot provide any definitive evidence. Also, in the case of catalytic converters, their cost may vary depending on the price of precious metals which would be unrelated to any developments in the technology.

4. COST IMPACT OF EMISSIONS REGULATIONS ON CONSUMERS

The nature of business is to make a profit. Thus, the goal of any company would be to pass any new costs, such as those incurred in complying with regulations, along to consumers. Eventually, one would expect most or all compliance costs to be passed along, otherwise a business would fail. However, there are many reasons related to strategic planning, market competition, cost management, and external market circumstances that might lead to absorbing the additional cost temporarily and across certain products.

How did manufacturers reflect the cost of new or altered technologies in vehicle prices in the short and long run?

Additional costs resulting from emissions regulations can either be absorbed by auto manufacturers, passed onto consumers through increased prices, or both. Real vehicle prices have historically increased sharply during periods of engine innovation. [27] Although the manufacturer's suggested retail price does not generally reflect the price paid by the consumer, this is typically the only information available and is a good indicator. Analysis of the CARBITS database reveals that vehicle retail prices have varied significantly over time and across vehicle classes. While the averages presented in Figure 4.1 represent the average price of vehicles offered, and are therefore not weighted for vehicle sales, they illustrate the variation between vehicle classes over time. Also, unweighted averages better reflect the response of the manufacturer while sales-weighted averages would be more representative of consumer response. Note during some years that the average vehicle price declined for one class but increased for another. For example, between 1979 and 1980, the average price of a subcompact car increased by $465 while midsize car prices decreased by over $2000 (2002 dollars).

The Bureau of Labor Statistics (BLS) annually calculates the amount of retail price increases attributable to quality improvements. Average retail price increases resulting from emissions improvements are shown in Figure 4.2. Marked spikes occurred in 1975 and 1980-1981, corresponding to the changes in emissions regulations. From 1981 to 1984, though, the emissions value includes both fuel economy and emissions control changes, which overstates the cost of compliance with emissions regulations. Another important aspect of these estimates is that they reflect only the price increases for changes made during that model year and therefore do not account for any reductions associated with learning or scale economies of changes that had been implemented in previous years. Thus, simply aggregating these price changes over time would also overestimate emissions control costs.

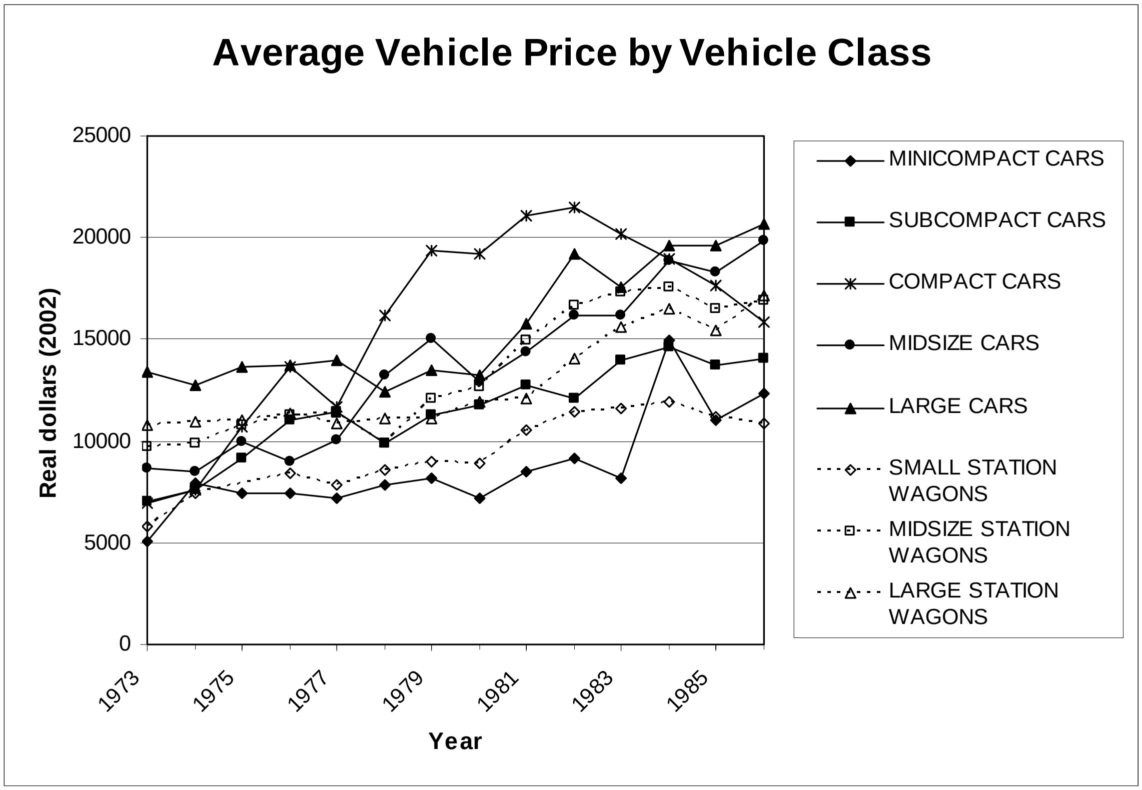


Figure 4.1 Average Vehicle Price by Vehicle Class

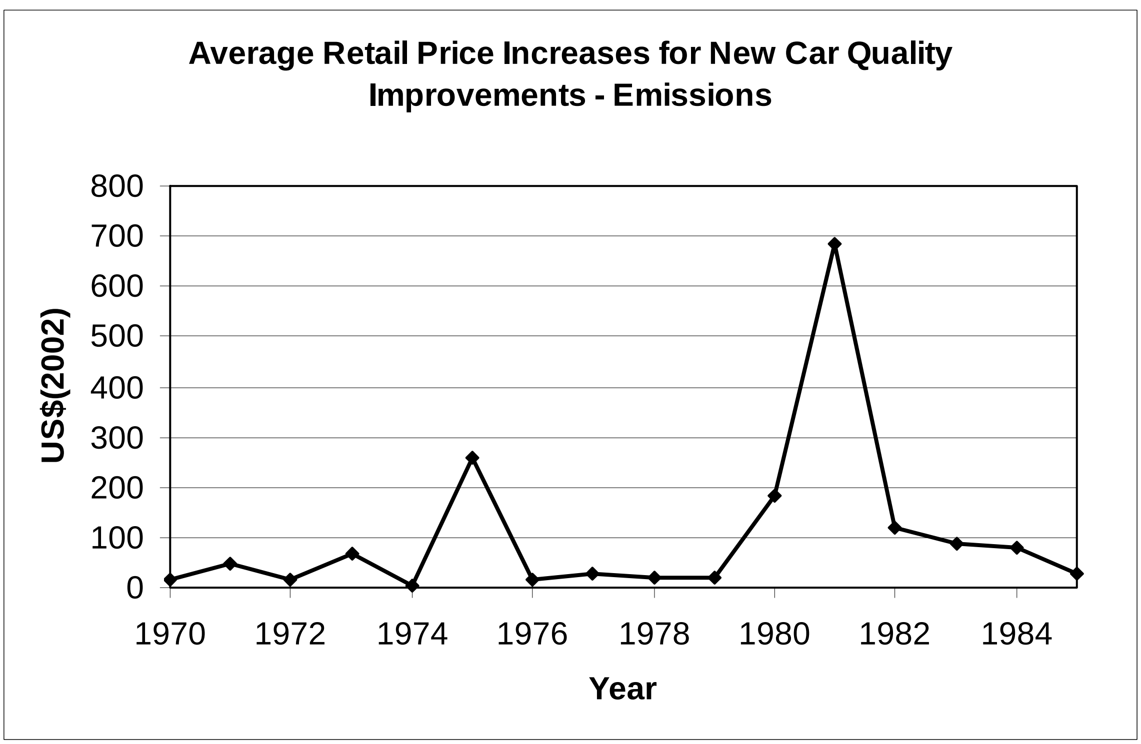


Figure 4.2 Average Retail Price Increases for Quality Improvements

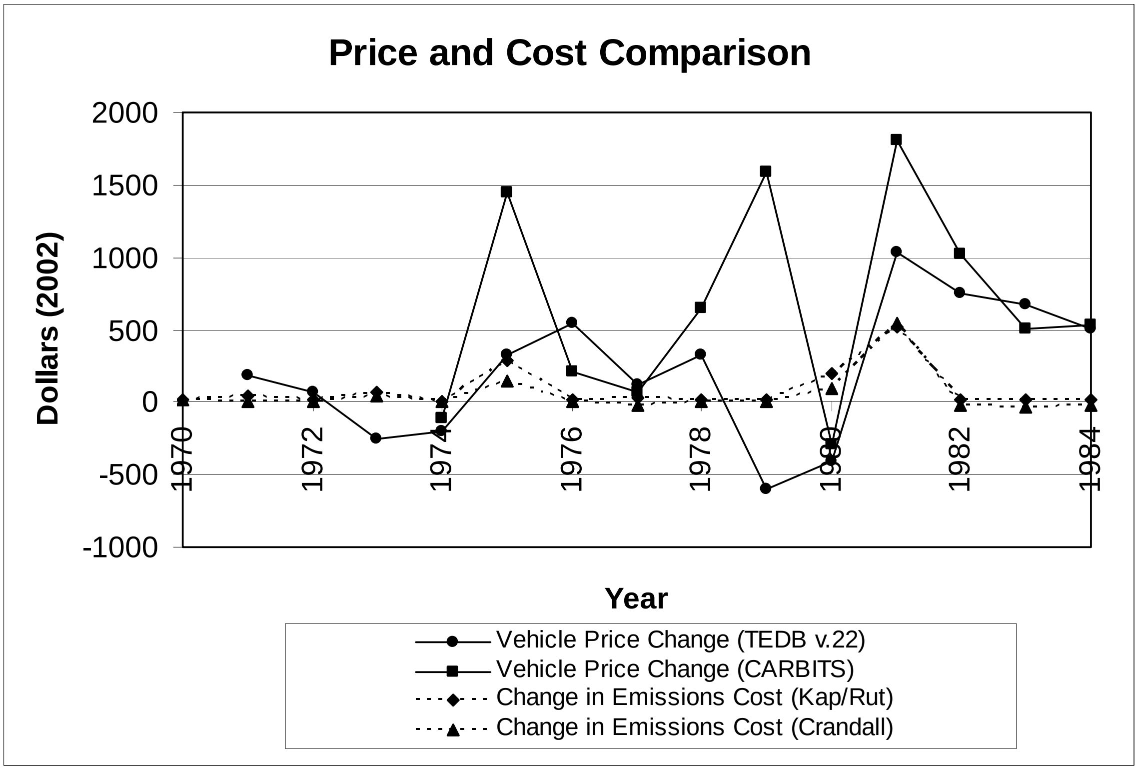


Figure 4.3 Price and Cost Comparison

However, price changes for emissions do not necessarily reflect changes in vehicle price, which would be what the consumer sees. Figure 4.3 shows these changes in vehicle prices and compares them to emission control costs. Compared to a sales-weighted average of passenger car prices (TEDB), the change in compliance cost exceeded the change in vehicle price for four years. However, compared to an unweighted average of prices for all passenger cars offered during the model year (CARBITS), the change in cost exceeded the change in price for only two years, though possibly three years if data for 1973 were available. The difference in 1979 could be attributed to the weighting, so that although the change in prices for vehicles offered by automakers increased, consumers heavily favored the less expensive models which lowered the weighted averaged. The fact that vehicle prices decreased during periods when emission control costs were estimated to have increased suggests that manufacturers were either absorbing the costs of compliance or reducing the cost of vehicles using other strategies. Whether these costs were fully passed on to consumers in the remaining years depends on what other changes were made to the vehicles for competitive purposes.

According to a recursive two-equation model of vehicle prices and profits by Crandall et al., manufacturers fully absorb the additional regulatory costs for the first year and then pass on approximately two-thirds of the costs to consumers the following year. They note that the full costs of regulation may eventually be included in the price of the vehicle. [18] Figure 4.4 shows that corporate profits fell dramatically during our case study periods but rebounded afterwards, suggesting that manufacturers are only

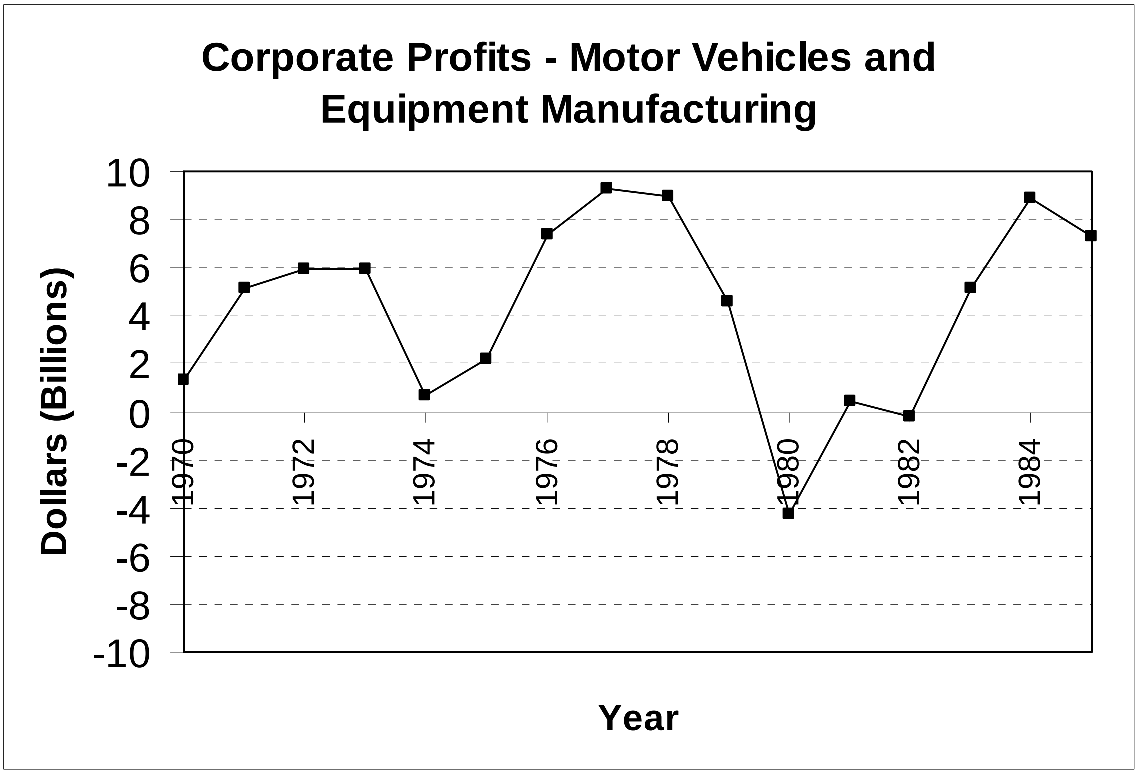


Figure 4.4 Corporate Profits
SOURCE: Bureau of Economic Analysis, Corporate Profits National Income and Product Accounts (NIPA) Tables

temporarily absorbing some of the costs. In his report on corporate strategies of automakers, Schnapp writes, "[t]here will be an inevitable tendency to pass through regulatory cost increases despite automaker concerns about possible adverse consumer behavior." [10] Economists view compliance costs as analogous to a unit sales tax on the industry. Thus, competitive firms will attempt to pass on as much of this tax as possible since subsidizing consumers indefinitely would reduce profit margins.

Another reason to expect that full costs will be passed on is that the costs fall with time as discussed in Section 3. Thus, a smaller amount—and presumably more tolerable to consumers, particularly if the increases are gradual—would be passed on. However, each manufacturer differs in their ability to absorb costs, which in turn influences what share of the costs are passed onto consumers. Larger automakers have more resources to absorb costs and consequently lower vehicle prices, allowing them to increase market share and outcompete the smaller manufacturers. [10] Passing on costs does not necessarily imply increased vehicle prices, though. More subtle strategies include converting standard equipment into optional equipment while simultaneously increasing the price of options, replacing materials (tires, fabric, carpet, etc.) with inferior substitutes, or eliminating some features all together such as vent windows or arm rests. [28]

To what extent were manufacturers able to raise prices to cover the cost increase associated with new or altered technologies in the short run and long run?

Although manufacturers tend to pass on regulatory costs to consumers, their ability to pass them on in the form of vehicle price increases is constrained by a number of factors. Most importantly, automakers preferred to keep vehicle price increases below the rate of inflation for fear that consumers would delay their purchases or downgrade to less luxurious (and less expensive) models. Especially during our case study periods, manufacturers were skeptical that consumers would not value the costs associated with emissions regulation; thus, any subsequent price increases could reduce both consumer demand and vehicle sales. In contrast, options such as power steering and power brakes could be installed as standard equipment at roughly list price without consequence. [17]

Industry profits are highly dependent upon unit volume. During the 1970s, Arvid Jouppi, an industry analyst, estimated that GM profits fell 2.5 times faster than unit sales, while Ford and Chrysler profits fell 3 and 4 times faster, respectively. [10] Thus, manufacturers are careful not to overprice their products in order to maintain market share and profitability. Another constraint on price changes was the increasing competition from foreign producers, which limited the extent to which domestic makers could transfer these compliance costs. An additional consideration when increasing vehicle prices is that prospective buyers often consider the change in price from their last vehicle purchase several years ago and not necessarily the change in price from the previous model year.

The initial pricing of a vehicle is a highly subjective and complex process. In addition to production costs, manufacturers also consider the return on investment, the return on sales, vehicle attributes (physical and psychological), market conditions, and used car prices. [28] Pricing strategies generally fall into two categories: cost pricing and image pricing. Cost pricing bases the price of a vehicle on the price of other models in the same vehicle segment with any necessary adjustments made for actual production costs. As the largest manufacturer with the ability to set the lowest prices, GM had most of the control over vehicle prices since models with similar attributes had to be priced equivalently to compete. Thus, both base vehicle prices and option prices fall within a narrow margin among all manufacturers. [17]

Image pricing bases the price of a vehicle on its appeal within the market and is the preferred pricing strategy as it tends to be more profitable. Luxury end models are typically priced using this method to capitalize on the status they confer to their owners. For instance, the Cadillac Seville and Lincoln Versailles were priced with more than $4500 (2002 dollars) of profit. [17] Although profit margins will vary for each model, manufacturers believe these variations are needed to capture all segments of the market. [10] For instance, automakers deliberately price the base model to have little profit in the hopes that consumers will purchase profitable options or else become brand loyal and upgrade to a more expensive model next time.

5. MANUFACTURER INCENTIVES DURING PERIODS OF CHANGING REGULATION

From 1975 through the early 1980’s, auto manufacturers needed to employ creative marketing strategies to maintain sales volume given the overall increase in vehicle costs and prices that resulted from investments in fuel economy improvement and other performance and amenities enhancements as well as emissions improvements. Conventional marketing tools such as heavy advertising can be successful in overcoming the public's resistance to a product. For example, the sluggish sales of the downsized 1978 Chevrolet Malibu eventually exceeded sales of its predecessor by 50 percent with the aid of a national advertising campaign. [10] The success of Ford's MPG campaign, GM's downsizing effort, and AMC's Buyer Protection Plan were all the result of effective advertising. However, underlying any successful campaign is the need for a quality product that appeals to consumers. Advertising can do little for a product that is perceived as inferior or a poor value. For instance, sales of GM's Vega compact car were slow despite heavy promotion, as consumers believed it to be of poor quality. [29] Incidents such as Ford's recall of 3.7 million cars in 1977 for product liability reasons also hurt consumer confidence in vehicle quality. [9] Furthermore, although effective advertising has the power to generate demand, it can only do so when the product is in line with consumer preferences. In the case of fuel efficient cars, miles-per-gallon-type advertising could not prevent consumers from purchasing larger, less fuel efficient cars when the fear of oil shocks subsided. [29]

Another strategy employed by automakers and dealers was the use of creative financing. Roughly two-thirds of new car were purchased with credit during the late 1970's. [10] In response to lackluster sales, auto dealers believed that reducing loan rates to below ten percent would boost demand. [30] Loan rates of course are related to

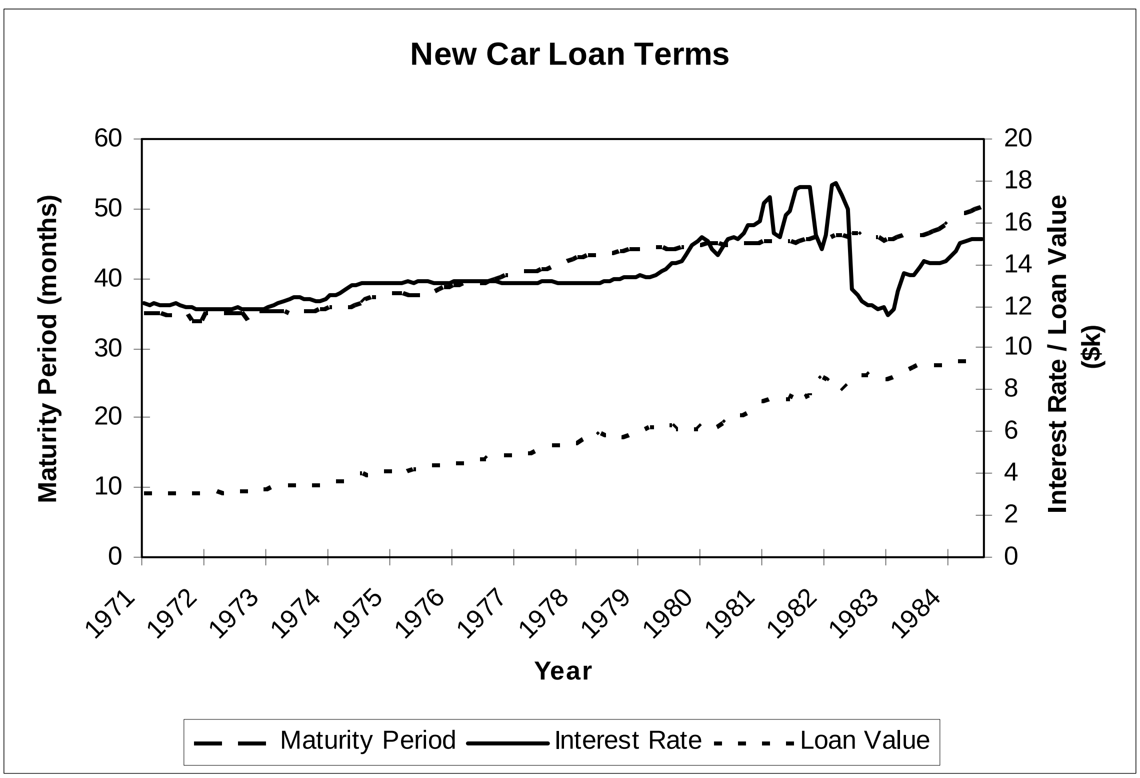


Figure 5.1 New Car Loan Terms
[Source: Federal Reserve Bank http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html]

market interest rates. Although car loan interest rates have recently fallen well below ten percent, they remained well above that level during our case studies, peaking in 1982 at almost 18 percent. (See Figure 5.1) Thus, as interest rates remained high and vehicle prices increased, the maturity period of the loans were extended so that monthly payments would not change drastically. In 1974, financial institutions offered 48 month loans for the first time on a widespread basis. Monthly payments in 1974 averaged $132, with four percent of buyers financing their cars with loan periods of 36 to 48 months. By 1976, this percentage was over 30 percent, and by 1978, 60 percent of buyers secured loans for 36 to 48 months, with average monthly payments of $174. [3, 10] While longer loan periods help mask increased vehicle sales prices, they are less effective when interest rates are high. Particularly during the early 1980's when interest rates peaked, higher monthly payments appear to have deterred consumers, with high interest rates accounting for 8 percent of lost sales. [31]

When advertising or financing strategies fail, manufacturers typically turn to dealer incentives or customer rebates to stimulate sales. Rebates are preferable to direct price reductions when inventory levels are high as they can be offered intermittently as opposed to more permanent price cuts. Although such programs are generally viewed as last resorts since they reduce profits, they are preferable to plant shutdowns or lost market share. Manufacturers also hope that increased sales can bring production back to more efficient levels. [29] The costs of incentives are not negligible, though. In 1975, the industry spent a total of $100 million (1975 dollars) on an incentives program that only raised monthly sales by 8 percent. [29] Chrysler was the only manufacturer to view the program as successful in light of the savings from reduced inventory. However, the effects of the rebates were short-lived and inventories rose again when the program ended.

This result is consistent with most other rebate programs, as incentives generally shift the timing of a vehicle purchase rather than generate sales that would not have occurred without incentives. The Congressional Budget Office estimated that a $1,300 rebate in 1980 would have generated only 0.8 million "new" sales for the year (possibly diverted from the used car market), while accelerating 1.7 million purchases that would have occurred within the next year or two and subsidizing the remaining 5.8 million purchases that would have occurred regardless of the rebate. [31] Figure 5.2 supports this finding with sales unresponsive to incentives by the end of the year, presumably because all demand had been

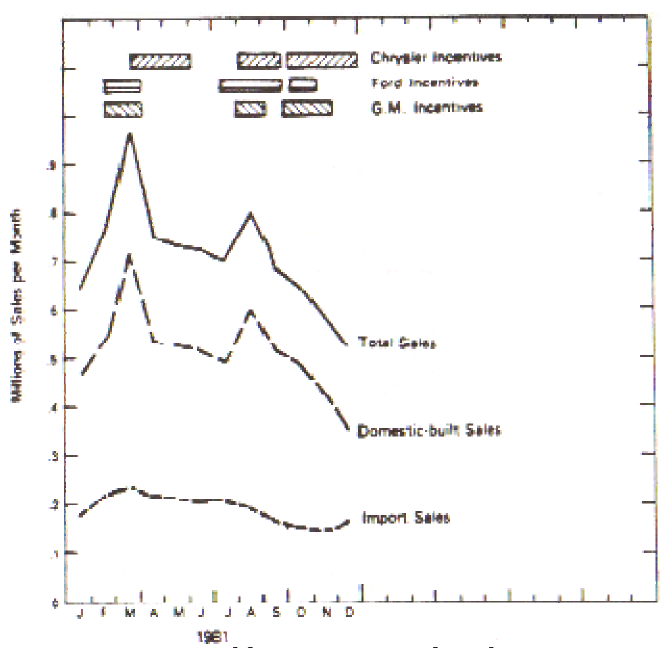


Figure 5.2 Monthly U.S. Auto Sales Showing Impact of 1981 Price Incentives
[Source: Reference 29]

fulfilled. [16]

Similar to advertising, though, the success of a rebate program also depends on the quality of the product being discounted. Offering of rebates does not automatically translate into increased sales, as some manufacturers that offer rebates actually fare worse than their competitors who did not offer rebates. [29] Some of the variation in effectiveness could be due to dealers who raise prices, either by reducing list price discounts or lowering the trade-in value, so that they profit from the rebate as well. [31]

Factors confounding sales volumes

Price alone is not the only factor affecting sales volume, though. While interest rates play an important role in a vehicle purchase decision, a survey by the National Automobile Dealers' Association in May of 1980 found that almost half of auto credit applications were refused compared to a typical rate of 10 to 15 percent. [as reported in *29*] The other major factor affecting sales volume is the general health of the economy. Vehicle sales generally change in accordance with the gross national product. Between 1973 and 1975, GNP declined by two to three percent while vehicle sales dropped by almost one-fourth. [31] 1980 and 1981 were similarly poor years in terms of both economic health and vehicle sales, with sales down by one-third compared to their peak in 1978. [18] Figure 5.3 also shows changes in vehicle sales to be highly correlated with the Conference Board's consumer confidence index, which gauges consumers' outlook on economic conditions. Both case study periods overlap with slumps in consumer confidence, confounding the effect of price increases on vehicle sales. However, given

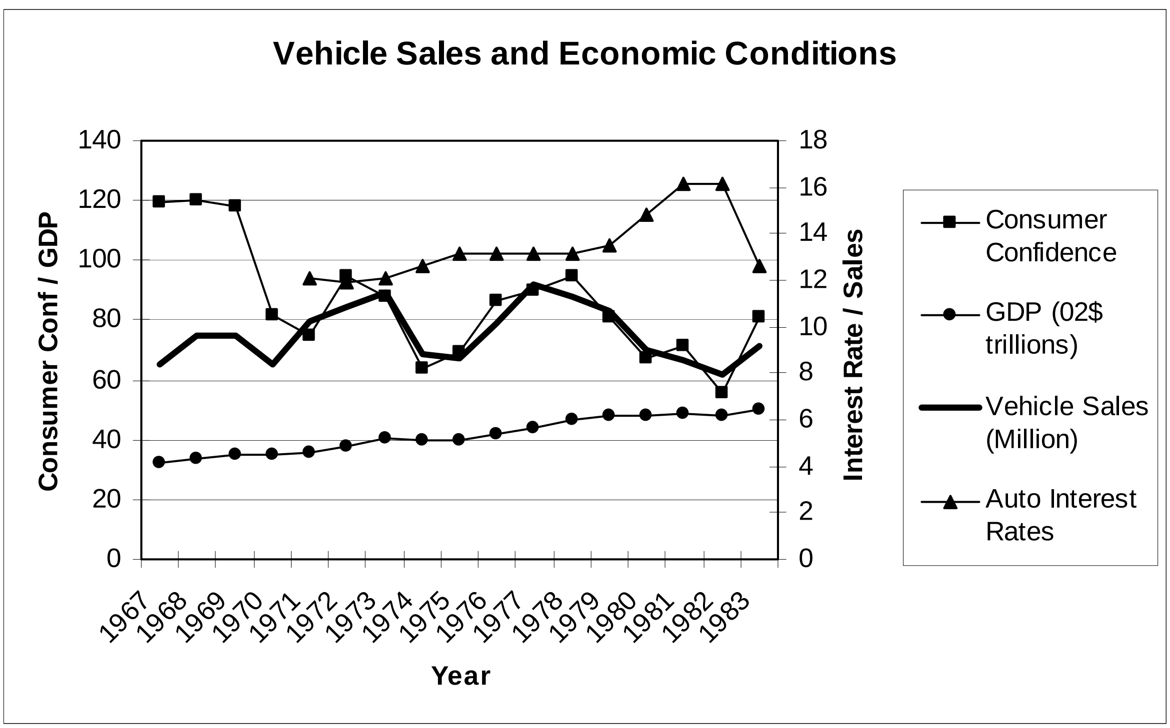


Figure 5.3 Vehicle Sales and Economic Conditions
SOURCES: Bureau of Economic Analysis, Federal Reserve Bank, The Conference Board, Transportation Energy Databook Volume 22

that emissions control equipment contributed only partially to vehicle price increases, aggregate vehicle sales were affected just in a minor way by the tightened emissions standards.

6. SUMMARY AND CONCLUSIONS

During both case study periods, automakers appeared to have responded to tightened emission standards by seeking technological solutions, as opposed to modifying vehicle attributes or changing in fleet mix. Thus, most manufacturers utilized oxidizing catalysts and three-way catalytic converters to meet the stricter standards. However, other factors such as engine system modifications, fuel injections, and onboard diagnostics and computer controls were important contributors to achieving compliance.

The cost of emissions control systems peaked in the early 1980s, at costs estimated to range from \$875 to \$1350 per vehicle (US\$2002). Costs declined through the 1980s as manufacturers learned to design and manufacture the technology better. Still, these compliance costs were not fully passed onto consumers in the form of increased vehicle prices, at least immediately. In some years when emission control costs increased substantially, average vehicle prices actually declined, confirming that other more important factors are at play. Those other factors influencing pricing include the desire to smooth sales over time and across models so as to balance planned production volumes with shifting demand. They also include myriad smaller goals, such as using pricing to boost sales of vehicles with high fuel economy so as to achieve the company’s CAFE standards, or making entry-level cars attractive to first-time buyers (who, it is hoped, will become brand loyal and later upgrade to more expensive and profitable vehicles). In addition, automakers use other non-pricing tactics to respond to regulatory changes and market shifts – including advertising and financing incentives.

Automaker response to new emissions regulations was not straightforward, uniform, nor transparent. We found, though, that even with aggressive new emission standards that imposed large cost increases, the effect on vehicle prices could not be detected. When the costs were significant, other cost and pricing factors seemed to be even more important. The added compliance costs associated with emission reduction were just one more factor used by companies in setting prices. Aggregate new car sales were affected only in a minor way by emissions regulations.

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APPENDIX A: DESCRIPTION OF CARBITS VEHICLE ATTRIBUTE DATABASE

A comprehensive database has been compiled for model years 1975-2002 for vehicle attributes at the make, model, and series level (though data at the series level are incomplete). EPA Fuel Economy Guide Reports provide the foundation for the database for model years 1978-2002. Additional attributes were added from Ward's Automotive Yearbooks, matching vehicles based upon engine displacement and fuel economy. Ward's also provided the basis for model years 1973-1977, during which period EPA data were not collected. Other vehicle characteristics were included using Consumer Reports tests of select vehicles. Because the number of vehicles tested by Consumer Reports is significantly fewer than the vehicles listed in Ward's, regression analysis will be used to devise a formula to obtain values for acceleration and maximum rated load for the remainder of the vehicles. The table below describes the variables currently included in the database and their sources.

		Data Source		
Column Header	**Description**	**EPA**	**Wards**	**CR**
Year	Model Year	X		
Class	EPA Vehicle Class (available only for 1978-2003)	X		
Manufacturer	Manufacturer name (note that some manufacturers have been omitted)	X		
carline name	Model name (note that vehicle series are not distinguished)	X		
wheelbase	Length of wheelbase in inches		X	
curb weight	Curb weight in pounds		X	
gross vehicle weight	Gross vehicle weight (curb weight + maximum rated load + passenger weight) in pounds for light trucks only		X	
maximum rated load	Maximum rated load in pounds			X
horsepower	Net horsepower		X	
traction	Traction Control: Blank=none; 1=optional; 2=standard			X
abs	Anti-lock Brakes: Blank=none; 1=optional; 2=standard		X	
hp-ca	Net horsepower for California vehicles (only early imports)		X	
msrp	Manufacturer suggested retail price in nominal dollars		X	
airbag	Airbags: Blank=none; 1=driver; 2= dual; 3=side; 4=rear/side; 5=ceiling		X	
Towing Capability (lb.)	Towing capability in pounds (mostly light trucks)			X
0-30	Acceleration 0-30mph in seconds			X
0-60	Acceleration 0-60mph in seconds			X
45-65	Passing acceleration in seconds			X
195-mile trip fuel economy	Consumer Reports road trip test fuel economy in mpg			X
Fuel Econ City Driving	Consumer Reports city test fuel economy in mpg			X
Fuel Econ Express-wayDriving	Consumer Reports highway test fuel economy in mpg			X
convertible?	blank=no; 1=yes		X	
veh type	1= luxury or sports car; 2= SUV; 3= minivan; 9=crossover		X	
cyl	Number of cylinders	X		
DISP CI	Engine displacement in cubic inches	X		

		Data Source		
Column Header	**Description**	**EPA**	**Wards**	**CR**
fuel system	Number of carburetor barrels or type of fuel injection: MPFI=multiport fuel injection; SFI=sequential fuel injection; IDI=indirect fuel injection; TBI=throttle-body injection; EFI=electronic fuel injection; VV=variable venture	X		
displ (liters)	Engine displacement in liters	X		
optional disp	Optional displacement in liters	X		
trans	Transmission type (A=automatic; M=manual; L=lockup)	X		
overdrive	OD=overdrive, EOD=electronic overdrive; AEOD=automatic overdrive	X		
catalyst	Y=catalyst; N=no catalyst	X		
drv	Drive axle type: FWD, RWD, 4WD	X		
cty	Adjusted city fuel economy	X		
hwy	Adjusted highway fuel economy	X		
cmb	Adjusted combined fuel economy	X		
ucty	Unadjusted city fuel economy	X		
uhwy	Unadjusted highway fuel economy	X		
ucmb	Unadjusted combined fuel economy	X		
fl	Fuel type: L=leaded gasoline; U=unleaded gasoline; D=diesel	X		
G	Gas guzzler vehicle	X		
T	Turbocharger	X		
S	Supercharger	X		
Type 2 Door	2-door vehicle passenger and luggage volume	X		
2pv	2-door passenger volume	X		
2lv	2-door luggage volume	X		
Type 4 Door	4-door vehicle passenger and luggage volume	X		
4pv	4-door passenger volume	X		
4lv	4-door luggage volume	X		
Type Hbk	Hatchback passenger and luggage volume	X		
hpv	Hatchback passenger volume	X		
hlv	Hatchback luggage volume	X		
fcost	Annual fuel cost in nominal dollars	X		
eng dscr 1	Engine description 1	X		
eng dscr 2	Engine description 2	X		
eng dscr 3	Engine description 3	X		
trans dscr	Transmission description	X		
cls	Valves per cylinder (2000 and later)	X		

APPENDIX B: VEHICLE CLASS DEFINITIONS FOR PASSENGER CARS

	PASSENGER AND CARGO VOLUME
SEDANS	
Minicompact	Under 85 cubic feet
Subcompact	85 to 99 cubic feet
Compact	100 to 109 cubic feet
Midsize	110 to 119 cubic feet
Large	120 or more cubic feet
STATION WAGONS	
Small	Under 130 cubic feet
Midsize	130 to 159 cubic feet
Large	160 or more cubic feet